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## ABSTRACT

This instructor's guide is designed for use by industrial vocational teachers in teaching a course on basic pneumatics. Covered in the individual units are the following topics: an introduction to pneumatics (including the operation of a service station hoist); fundamentals and physical laws; air compressors (positive displacement compressors; velocity compressors; service and operation of a hand bicycle pump; and compressor installation, safety, and noise control); compressor accessories (air intake, silencers, and mufflers; air coolers and air dryers; receiver tanks; air filter, regulator, and lubricators; and disassembling, inspecting, and reassembling an air filter-regulator-lubricator unit); actuators (cylinders, pressure boosters, and pneumatic motors); and pressure and flow measurement. Each unit contains a note on the scope of the unit, lesson objectives, supplementary teaching and learning items, a student information assignment, an introduction, an outline of information to be covered, evaluation items, answers to the evaluation items, and transparency masters. (MN)

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Instructor's Guide

## BASIC PNEUMATICS

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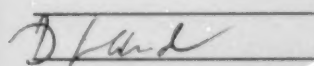
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## FOREWORD

The industrial vocational instructors of today face the challenge of helping students acquire skills and knowledge necessitated by a growing and changing industry. Because the competition and skill requirements for jobs are greater than ever, students in industrial vocational programs must receive the best education possible to actively compete effectively in today's market.

This guide, Basic Pneumatics, has been written to compliment the Fluid Power/Basic Hydraulics guide. Two additional guides, Fluid Power Systems Maintenance and Operation and Fluid Power Systems Designs and Modification, are in the process of being written.

Because of the similarities between pneumatics and hydraulics, some of the materials discussed in Fluid Power/Basic Hydraulics guide has been repeated in this guide to reinforce the student's understanding of the subject. To avoid repetition, a unit on flow, pressure, and directional valves is not included in this guide. After the completion of Unit V, it is suggested that instructors review Unit II, Lesson plan 14, Introduction to Hydraulic Valves, from the Fluid Power/Basic Hydraulics guide.

Effort has been made to present demonstration lessons which are easy to perform and which will give the students hands-on training on some pneumatics units and components. However, the demonstration lessons presented are neither comprehensive nor universally available in every school. Therefore, instructors, depending on the teaching and laboratory resources they have, are encouraged to modify and/or add demonstration lessons whenever it is deemed necessary and helpful.

Suggested student reading assignments that are referenced in this guide are from (a) Stewart, L. Harry. Pneumatics and Hydraulics. 3rd ed. Indianapolis, IN: Theodore Audel and Co., 1978 and (b) Industrial Pneumatic Technology, Bulletin 0275-B1. Parker Hannifin Corporation, 1980.

An advisory committee composed of various industrial vocational instructors, representatives from community colleges, representatives from industry, and state department personnel were instrumental in the developing and writing of this Basic Pneumatics curriculum guide.

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## HOW TO USE THIS GUIDE

This guide contains the instructional analysis which lists the information and demonstration lessons for the course. A competency profile is also included which provides a checklist of the major competency areas to be achieved by each student plus a certificate of recognition. This profile provides a permanent record for student, instructor, and/or industry representatives to present or review when determining student competencies. Each instructional unit contains both informational and demonstration lessons. Lessons are planned for one class period of instruction; however, adjustments will need to be made to adapt to individual situations.

The information lessons include a title page, outline (key points), transparency masters, interaction items (review points), and evaluation items. The demonstration (skill) lessons include a title page, steps of procedure (operations), interaction items, and evaluation items.

## INFORMATION LESSON COMPONENTS

### Title Page: (White; instructor only)

1. Objectives: Each unit of instruction is based on behavioral objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Behavioral objectives are stated in two forms, 1) the scope of unit states the subject matter to be covered in each unit of instruction, and 2) the lesson objective states the student performance necessary to reach the unit objective.

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit. Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When a teacher adds objectives, the needed information sheets and evaluation items should be added also.

2. Supplementary Teaching/Learning Items: This is a list of transparency masters prepared for this lesson.
3. Informational Assignment: This identifies reading assignments for the student. Assignments are given in chapters or units rather than pages to accommodate the change of textbook editions.
4. References: Additional information is listed here which would be helpful to the instructor. Space is provided for the instructor to list his/her own sources. This allows the instructor to assemble materials quickly when needed for presentation, review, or revision of the lesson.
5. Introduction: This is a short, precise statement describing the importance of the lesson. It addresses the question of "How do I get my students set in a frame of mind to pay attention to the lesson?" This statement should be motivational to help the student establish the meaning of the lesson.

**Outline (Key Points):** (Yellow: instructor and student)

These sheets provide content essential for meeting the cognitive (knowledge) objectives of the units. The teacher will find that information sheets serve as excellent guides for presenting the background knowledges necessary to develop the skills specified in the unit objectives.

Student should read these sheets before the information is discussed in class. Students may take additional notes on the information sheets.

Transparencies (TM) are keyed to the outline for proper use.

**Transparency Masters:** (White; instructor and student)

Transparency masters provide information in a special way. The students may see as well as hear the material presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective for such activities as identifying and locating the parts and construction of equipment used.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion. The transparency masters also serve as a source for the instructor to make his/her own handouts for distribution to the class. In fact many of the transparency masters in this guide, especially those containing fine print or a lot of information, are best handled, at the instructor's discretion, in this manner. An attempt was made not to duplicate a transparency master as a separate handout.

**Interaction Items:** (Blue; instructor only)

This sheet which is prepared for the instructor only helps in the planning of verbal involvement with students over the lesson content. Key points about the lesson are listed in question form in order to obtain feedback. These questions may then be used at anytime during the lesson as a quick check of student comprehension and to call attention to key points.

Classroom, laboratory, shop, or other activities are listed at the bottom of this page. Activities should be planned to follow each lesson presentation. This provides a means of reinforcing a desired level of learning.

**Evaluation Items:** (Pink; instructor and student)

Paper and pencil evaluations have been constructed to measure student achievement of each objective listed in the lesson. Teachers are encouraged to construct and add questions of their own to the test. Answers are provided on the instructor's copy only to aid in grading.

**DEMONSTRATION (SKILL) LESSON COMPONENTS**

**Title Page and Interaction Items:**

(These components are the same for the information and demonstration lessons. See explanation under information lesson components for further details.)



**Steps of Procedure (Operations):** (Green; instructor and student)

This component is designed for use in an operating (on-job) situation. The instructor should demonstrate the skills outlined on this sheet. Procedures outlined on this sheet give direction to the skill being taught and allow both student and instructor to check student progress toward the accomplishment of the skill. This component provides a ready outline for a student to follow if a demonstration has been missed.

**Evaluation Items:** (Pink; instructor and student)

This sheet contains a condensed check list for each of the steps of procedure (operations) included in this lesson. Appropriate space has been allowed for the instructor to check "yes" or "no" as to the student's performance. The instructor is encouraged to add any additional comments as this sheet becomes a permanent record of a student's capabilities and can be used for future reference.

**COMPETENCY CERTIFICATE**

This certificate is in the back of this curriculum guide. It is a compilation of the tasks performed in the Demonstration Lessons. It provides the student and instructor with a permanent record of the student's achievements in this Basic Pneumatics Guide.

## BASIC PNEUMATICS

### Demonstration

### Information

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#### INTRODUCTION TO PNEUMATICS

---

1. Introduction to Pneumatics
2. Operation of Service Station Hoist

---

#### FUNDAMENTALS AND PHYSICAL LAWS

---

1. Fundamentals and Physical Laws

---

#### AIR COMPRESSORS

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1. Positive Displacement (pressure) Compressors
2. Velocity (dynamic) Compressors
3. Service and Operation of Bicycle Hand Pump
4. Compressor Installation, Safety, and Noise Control

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#### COMPRESSOR ACCESSORIES

---

1. Air Intake, Silencer, Muffler
2. Air Coolers and Air Dryers
3. Receiver Tanks
4. Air Filter-Regulator-Lubricator
5. Disassemble, Inspect, and Reassemble an Air Filter-Regulator-Lubricator Unit

**Demonstration****Information**

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---

**ACTUATORS**

---

1. Cylinders
2. Pressure Boosters
3. Pneumatic Motors

---

---

**FLOW AND PRESSURE MEASUREMENT**

---

1. Pressure and Flow Measurement

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT 1 : INTRODUCTION TO PNEUMATICS

SCOPE OF UNIT:

After the completion of this unit, the student should be able to define pneumatics, hydraulics and other related terms. The student should be able to compare and contrast pneumatics with hydraulics, list safety practices when working on pneumatic and hydraulic systems, and discuss the advantages and disadvantages of pneumatic systems. The student should be able to identify the components of a basic pneumatic system and safely operate a service station hoist system. This knowledge will be evidenced by correctly performing the procedures outlined in the demonstration lesson and by scoring 85 percent on the evaluation items.

INFORMATION TOPIC: I-1

INTRODUCTION TO PNEUMATICS  
(Lesson Title)

LESSON OBJECTIVES - THE STUDENT SHOULD BE ABLE TO:

1. Match terms and definitions of pneumatics, hydraulics and related terminology.
2. Name the fluid most commonly used in pneumatic systems and state reasons for its use.
3. Discuss the advantages and disadvantages of pneumatic and hydraulic systems.
4. Discuss the similarities and dissimilarities of pneumatics and hydraulics.
5. Discuss the advantages of pneumatic systems over other systems.
6. List six safety practices for working on pneumatic and hydraulic systems.
7. Identify components of a typical pneumatic system.
8. Identify basic components of service station hoist system.

SUPPLEMENTARY TEACHING/LEARNING ITEMS

1. TM 1: Typical Pneumatic System and Instrumentation
2. TM 2: Operating Principles of Service Station Hoist



### **INFORMATIONAL ASSIGNMENT: (Student)**

Study the outline on the following pages prior to class time and be ready to discuss.

### **REFERENCES: (Instructor's Additional Information)**

### **INTRODUCTION:**

Man has used compressed air (pneumatics) since the early hunter developed blow-guns using compressed air from human lungs. Perhaps the first compressor was the blower which has been used, and is still being used in some parts of the world, in basic metal smelting. However, the development of pneumatics remained relatively static until the late eighteenth century when mechanical compressors were developed to generate air pressure as high as 15 pounds per square inch (psi). By the early nineteenth century, pneumatic systems were developed that compressed air to pressures up to 90 psi. Large industrial and construction projects began to use compressed air as a source of power. For instance, an eight-and-a-half mile tunneling project in Mt. Cenis in the Alps, which would have required 30 years of manual drilling, took only 14 years using pneumatic drills.

Today, although pneumatics is not the major source of power, it is used in virtually every machine. Air brakes, air motors, drilling, diecasting, pressing, grinding, riveting, hoisting, conveying, and paint spraying are some uses of compressed air.

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT 1 : INTRODUCTION TO PNEUMATICS

INFORMATION TOPIC: I-1

OUTLINE: (Key Points)

I. Terms and definitions

- A. **Pneumatics** - the study of gases in motion or at rest
- B. **Hydraulics** - the study of liquids in motion or at rest
- C. **Fluid** - a substance which does not have shape of its own
- D. **Liquid** - a fluid which is relatively incompressible such as water and oil
- E. **Gas** - a fluid which is compressible such as air
- F. **Incompressible** - a substance which does not change in volume when subjected to pressure
- G. **Compressible** - a substance which changes in volume when subjected to pressure

II. Common pneumatics fluid

- A. Air
- B. Reasons for using air
  - 1. Readily available
  - 2. Relatively safe
  - 3. Easy to distribute

III. Advantages and disadvantages of pneumatic as compared to hydraulic systems

(NOTE: Due to considerations of practicality, cost, size, flexibility, and control, fluid mechanics often replaces classical mechanics.)

- A. Advantages
  - 1. Flexibility

- a. Fast response to start and stop control signals.
  - b. Forces can be magnified or reduced easily.
- 2. Efficiency - minimum power loss due to friction
- 3. Simplicity
  - a. Fewer moving parts and points of wear than mechanical systems.
  - b. Ease of installation and maintenance
- 4. Compactness - more compact than electrical or mechanical systems of equal horsepower
- 5. Economy
  - a. Low maintenance and operating cost
  - b. Long service life
- 6. Environmental - can be made air, water, and noise pollution free

**B. Disadvantages**

- 1. Initial cost
- 2. Pressurized fluid is potentially dangerous.
- 3. Leakage
- 4. Precise control more difficult than hydraulics
- 5. Compressibility; less efficient

**IV. Similarities and dissimilarities of pneumatics and hydraulics**

**A. Similarities**

- 1. Both use fluid energy
- 2. Both transmit pressure undiminished in every direction
- 3. Both provide flexibility in the central control mechanism

**B. Dissimilarities**

- 1. Pneumatics use gaseous mass, normally air.
- 2. Hydraulics use liquids, normally oil.

V. Advantages of pneumatic systems over other systems

- A. Present no fire and electrical shock hazards; nonexplosive.
- B. Clean.
- C. More compact - working components are smaller.
- D. Rugged and can be used in adverse environmental conditions, i.e., underwater and in mines.
- E. Relatively cheap
- F. Overheats less.
- G. Stalled pneumatic systems recover more easily than mechanical systems once the stalling force is released.

VI. Safety practices when working with pneumatic and hydraulic systems

- A. Support booms and attachments before working on the system.
- B. Operate all control levers to insure that system pressure has been relieved.
- C. Loosen lines and components in a circuit slowly to relieve trapped pressure.
- D. Observe normal shop safety practices including wearing of safety glasses and helmets.
- E. Make sure safety features such as pressure gage and pressure relief valves are operational.
- F. Stop system and repair non-operational components and replace defective and worn out parts.

VII. Typical pneumatic system and instrumentation (TM-1)

- A. Air inlet - inlet provided with air filter, strainer, or separator
- B. Motor - electric or diesel engine to drive the compressor
- C. Compressor - a device which compresses or increases the pressure of air (gas) from the atmosphere
- D. Intercooler - a device which cools the air between the compressor stages of a multiple stage compressor
- E. Aftercooler - a device which cools the air after it has been compressed



- F. Air drier - a device with drying agent or refrigeration chamber to dry the compressed air
- G. Check valve - a valve that allows flow in one direction only
- H. Receiver - a sealed container in which compressed gas is stored as a source of pneumatic power
- I. Safety valve - valve that relieves or releases excessive pressure in pneumatic systems
- J. Stop valve - a valve to stop or shut off the flow of compressed air or fluid
- K. Filter - a device to retain contaminant particles
- L. Pressure regulator - a device to control pressure
- M. Pressure gage - an instrument which indicates or records the pressure of the system to which it is connected
- N. Lubricator - a device which adds a controlled amount of lubricant into a pneumatic system
- O. Direction control valve - a valve whose function is to direct or prevent flow through selected passages
- P. Actuator - a device which converts the pressurized fluid potential energy into mechanical force or motion
- Q. Silencer/muffler - devices for reducing gas flow noise
- R. Air line - pipe or conduit through which power, signal and/or air are transmitted or transported
- S. Drip legs - chamber to remove air-entrained water droplets
- T. Drain - a mechanism to purge condensed water from system

#### VIII. Operation of service station hoist (TM 2)

- A. Basic components
  - 1. Motor to drive air compressor
  - 2. Compressor to increase the air pressure
  - 3. Receiver tank to store the compressed air for future use
  - 4. Air line to transmit the air power

5. Control valves to let air into and out of the hoist
6. Oil to lubricate the moving parts and help transmit the power to lift or lower the hoist

**B. Hoisting or lifting procedures**

1. Control valve (1) is opened to let the compressed air from the receiver tank into the hoist.
2. Control valve (2) is closed.
3. Compressed air enters cylinder (2).
4. Cylinder (2) is pushed up to lift load.

(NOTE: Object to be lifted should be checked for stability and balance.)

**C. Lowering procedures**

1. Control valve (1) is closed.
2. Control valve (2) is opened.
3. Compressed air in cylinder (2) is forced to escape through control valve (2).
4. Air pressure in cylinder (2) decreases and load is lowered.

(NOTE: Lifting and lowering of load should be done slowly.)

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT 1 : INTRODUCTION TO PNEUMATICS

INFORMATION TOPIC: I-1

### EVALUATION ITEMS

1. Match the terms on the right with the correct definition on the left.

- |        |                                                                        |                   |
|--------|------------------------------------------------------------------------|-------------------|
| ___ a. | A substance which does not change in volume when subjected to pressure | 1. Pneumatics     |
| ___ b. | A fluid which is highly compressible                                   | 2. Hydraulics     |
| ___ c. | A fluid which is relatively incompressible                             | 3. Fluid          |
| ___ d. | The study of gases in motion or at rest                                | 4. Liquid         |
| ___ e. | A substance which does not have shape of its own                       | 5. Gas            |
| ___ f. | The study of liquids in motion or at rest                              | 6. Incompressible |
| ___ g. | A substance which changes in volume when subjected to pressure         | 7. Compressible   |

2. Name the fluid most commonly used in pneumatic systems and state why it is common.

3. a. List and discuss six advantages of pneumatic and hydraulic systems over other systems.

1)

2)

3)

4)

5)

6)

- b. List and discuss three disadvantages of pneumatic and hydraulic systems.

1)

2)

3)

4. Discuss the similarities and dissimilarities of pneumatics and hydraulics.



5. List at least six advantages of pneumatic systems over other systems.

a.

b.

c.

d.

e.

f.

6. List six safety practices when working on pneumatic and hydraulic systems.

a.

b.

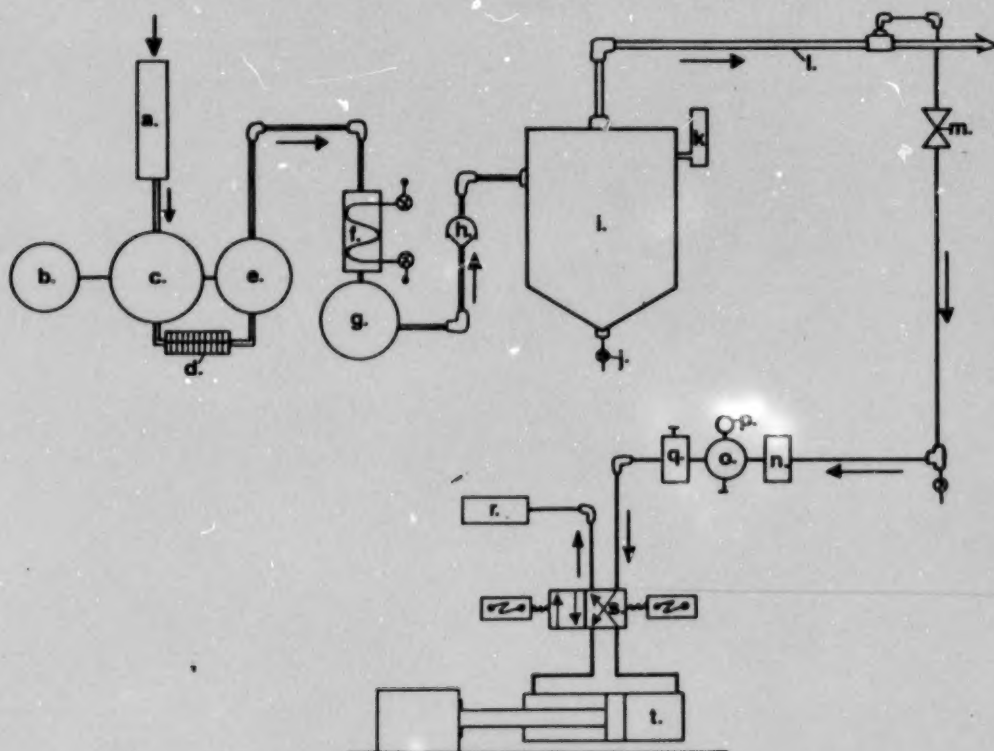
c.

d.

e.

f.

7. Identification - for the typical pneumatic system shown below write the name of each component of the system in the space next to the appropriate letter.

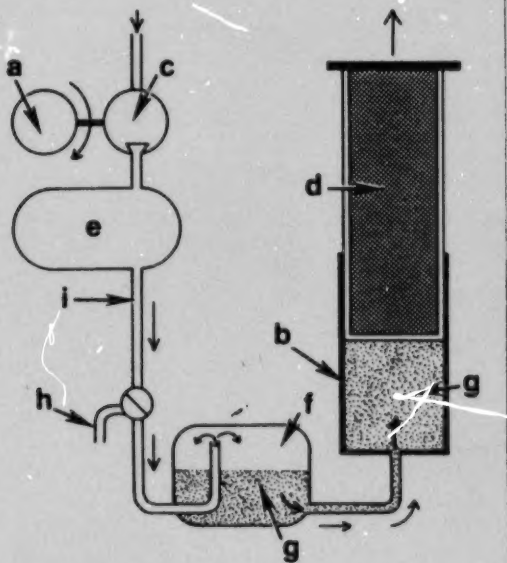


a. \_\_\_\_\_  
 b. \_\_\_\_\_  
 c. \_\_\_\_\_  
 d. \_\_\_\_\_  
 e. \_\_\_\_\_  
 f. \_\_\_\_\_

g. \_\_\_\_\_  
 h. \_\_\_\_\_  
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 k. \_\_\_\_\_  
 l. \_\_\_\_\_  
 m. \_\_\_\_\_

n. \_\_\_\_\_  
 o. \_\_\_\_\_  
 p. \_\_\_\_\_  
 q. \_\_\_\_\_  
 r. \_\_\_\_\_  
 s. \_\_\_\_\_  
 t. \_\_\_\_\_

8. Identification: write the names of the components of service station hoist system in the space next to the appropriate letter.



- |    |       |    |       |    |       |
|----|-------|----|-------|----|-------|
| a. | _____ | d. | _____ | g. | _____ |
| b. | _____ | e. | _____ | h. | _____ |
| c. | _____ | f. | _____ | i. | _____ |

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT I : INTRODUCTION TO PNEUMATICS

INFORMATION TOPIC: I-1

ANSWERS TO EVALUATION ITEMS

1.
  - a. 6
  - b. 5
  - c. 4
  - d. 1
  - e. 3
  - f. 2
  - g. 7
2. Air
  - a. Readily available
  - b. Relatively safe
  - c. Easy to distribute
3. Discussion should include:
  - A. Advantages
    1. Flexibility
      - a. Fast response to start and stop control signals
      - b. Forces can be magnified or reduced easily
    2. Efficiency - minimum power loss due to friction
    3. Simplicity
      - a. Have fewer moving parts and points of wear than mechanical systems.
      - b. Ease of installation and maintenance.
    4. Compactness - more compact than electrical or mechanical systems of equal horsepower
    5. Economy
      - a. Low maintenance and operating cost
      - b. Long service life
    6. Environmental - can be made air, water, and noise pollution free
  - B. Disadvantages (any of the following)
    1. Initial cost
    2. Pressurized fluid is potentially dangerous.
    3. Leakage
    4. Precise control more difficult than hydraulics
    5. Compressibility; less efficient
4. Similarities
  - a. Both use fluid energy.
  - b. Both transmit pressure undiminished in every direction.
  - c. Both provide flexibility in the central control mechanism.

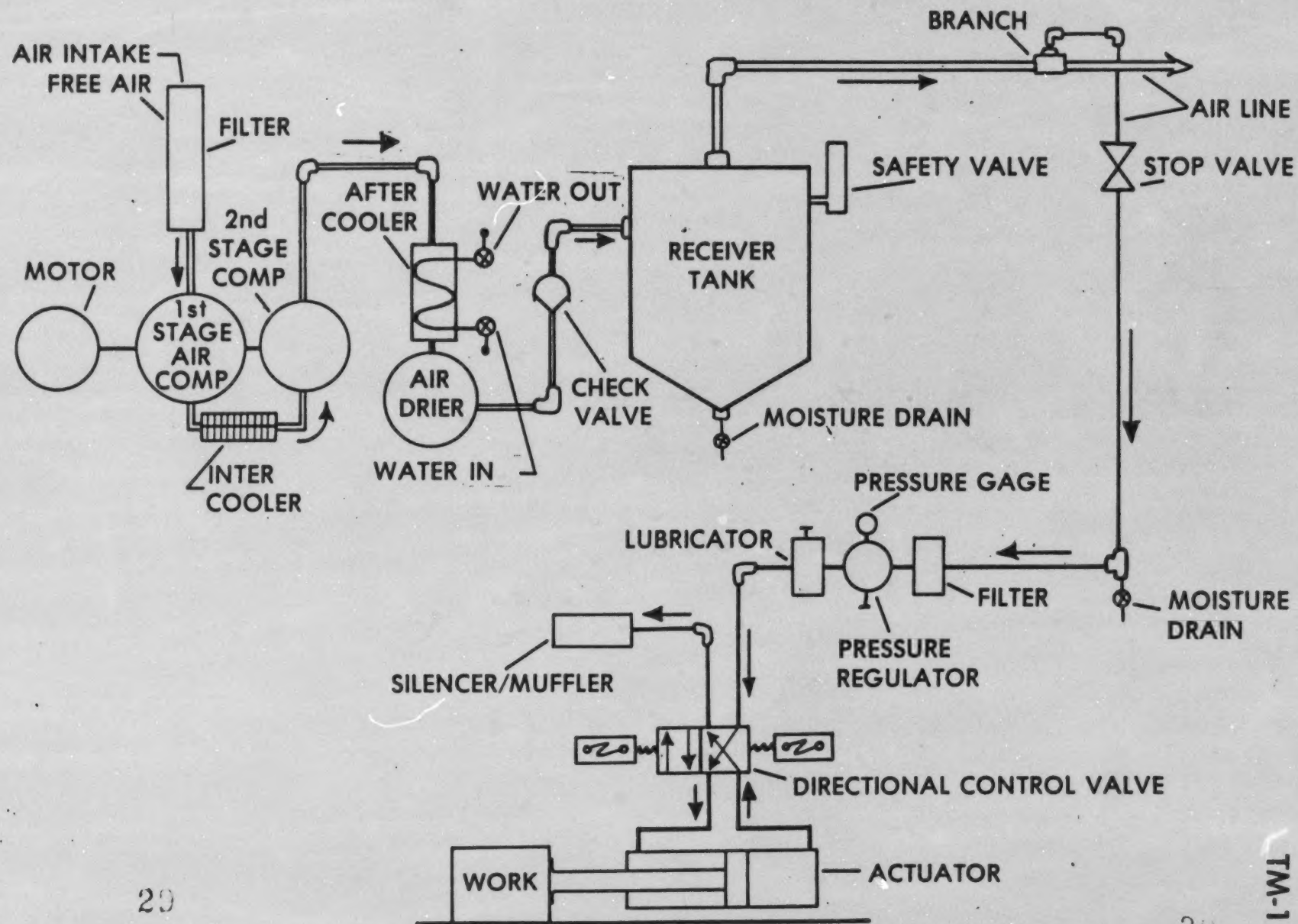


Dissimilarities

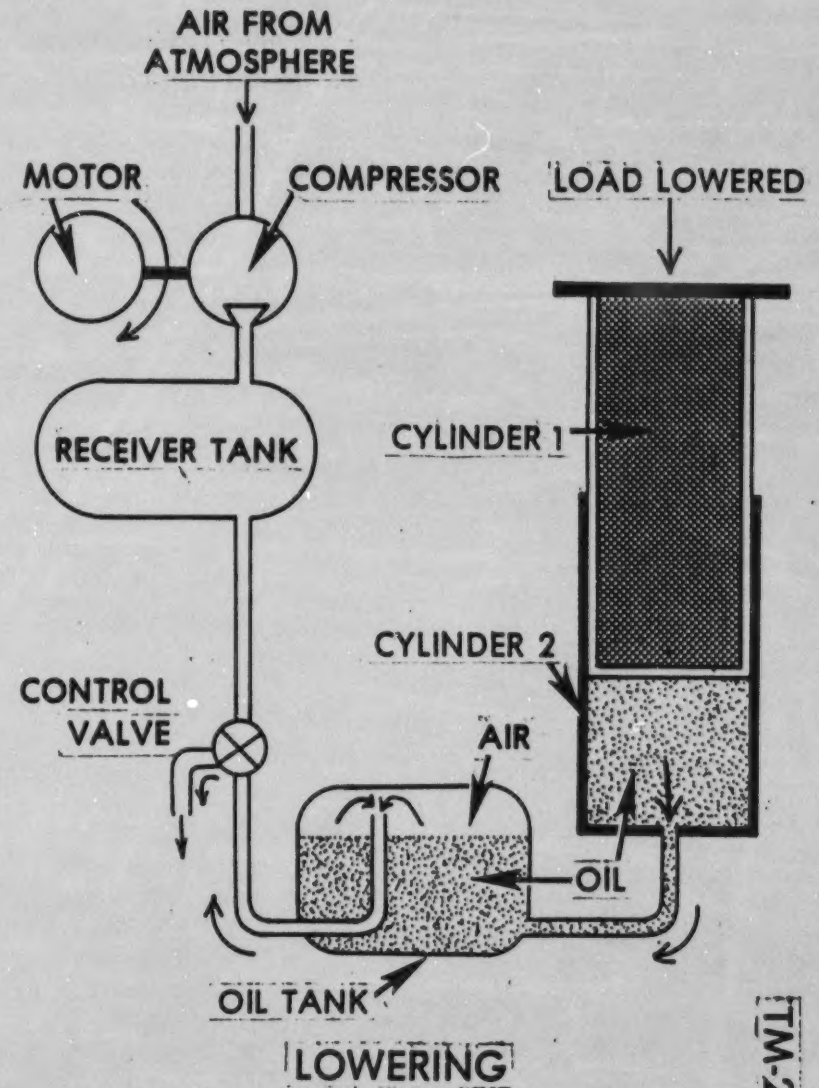
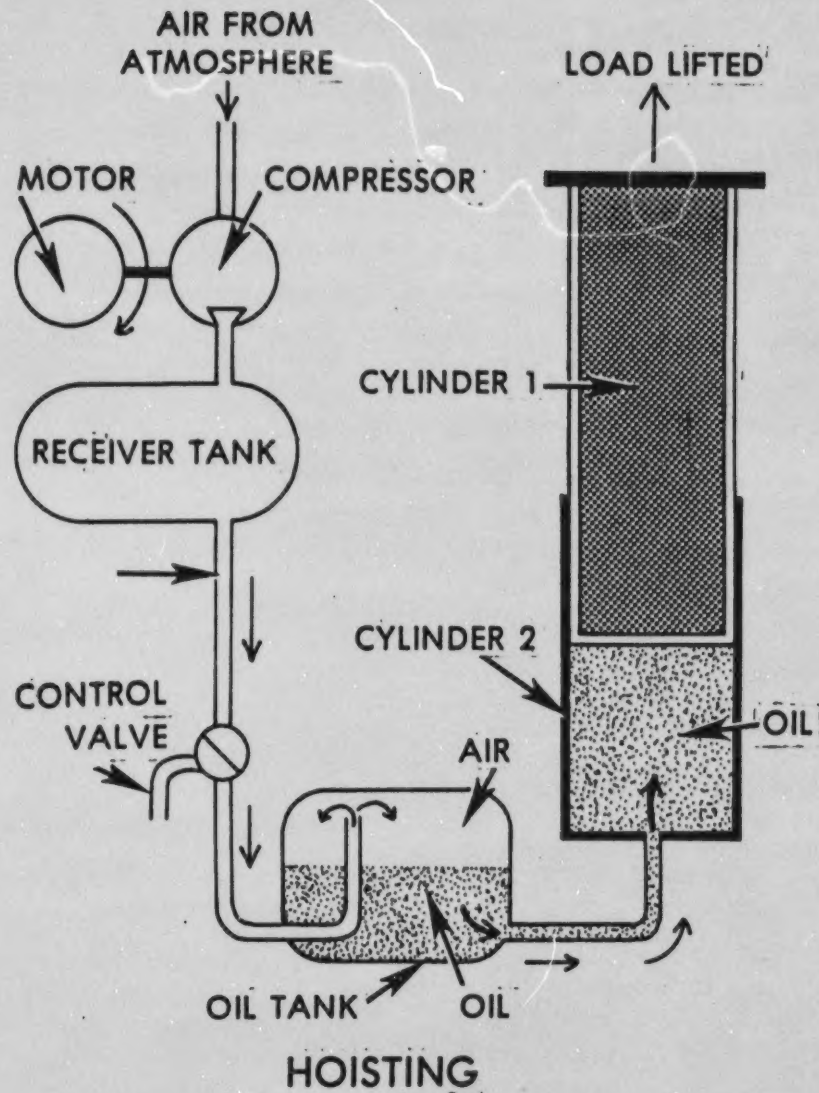
- a. Pneumatic systems use gaseous mass, normally air.
  - b. Hydraulic systems use liquids, normally oil.
5. Advantages of pneumatic systems over other systems
- A. Present no fire and electrical shock hazards; nonexplosive.
  - B. Clean.
  - C. More compact; working components are smaller
  - D. Rugged and can be used in adverse conditions such as underwater and in mines.
  - E. Relatively cheap
  - F. Overheats less.
  - G. Stalled pneumatic systems recover more easily than mechanical systems once the stalling force is released.
6. Safety practices when working with pneumatic and hydraulic systems
- A. Support booms and attachments before working on the system.
  - B. Operate all control levers to insure that system pressure has been relieved.
  - C. Loosen lines and components in a circuit slowly to relieve trapped pressure.
  - D. Observe normal shop safety practices including wearing of safety glasses and helmets.
  - E. Make sure safety features such as pressure gage and pressure relief valves are operational.
  - F. Stop system and repair non-operational components and replace defective and worn-out parts.
- 7.
- a. Filler
  - b. Motor
  - c. First stage air compressor
  - d. Intercooler
  - e. Second stage compressor
  - f. Aftercooler
  - g. Air drier
  - h. Check valve
  - i. Receiver tank
  - j. Moisture drain
  - k. Safety valve
  - l. Air line
  - m. Stop valve
  - n. Filter
  - o. Pressure regulator
  - p. Pressure gage
  - q. Lubricator
  - r. Silencer/muffler
  - s. Directional control valve
  - t. Actuator

8.
  - a. Motor
  - b. Cylinder (2)
  - c. Compressor
  - d. Cylinder (1)
  - e. Receiver tank
  - f. Air
  - g. Oil
  - h. Control valve
  - i. Air line

# TYPICAL PNEUMATIC SYSTEM AND INSTRUMENTATION



# OPERATING PRINCIPLES OF SERVICE STATION HOIST



TM-2



LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT 1 : INTRODUCTION TO PNEUMATICS

SCOPE OF UNIT:

After the completion of this unit, the student should be able to define pneumatics, hydraulics and other related terms. The student should be able to compare and contrast pneumatics with hydraulics, list safety practices when working on pneumatic and hydraulic systems, and discuss the advantages and disadvantages of pneumatic systems. The student should be able to identify the components of a basic pneumatic system and safely operate a service station hoist system. This knowledge will be evidenced by correctly performing the procedures outlined in the demonstration lesson and by scoring 85 percent on the evaluation items.

DEMONSTRATION: I-2

OPERATION OF SERVICE STATION HOIST  
(Lesson Title)

LESSON OBJECTIVES - THE STUDENT SHOULD BE ABLE TO:

1. Identify the basic components of a service station hoist system.
2. Operate a hoist system.
3. Practice safety precautions and measures while operating the system.

SUPPLEMENTARY TEACHING/LEARNING ITEMS:

1. TM 2 from Unit I, Lesson plan 1.

**INFORMATIONAL ASSIGNMENT: (Student)**

1. Review Operating Principles of Service Station Hoist (Unit I, Lesson plan 1).
2. Read service literature or manual available for the hoist system used in Demonstration Lesson.

**REFERENCES: (Instructor's Additional Information)**

Manufacturer's service manual for the hoist system being demonstrated.

**INTRODUCTION:**

Demonstrate knowledge in a hands-on application of the operation of a hoist system and related safety practices.

LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT 1 : INTRODUCTION TO PNEUMATICS

DEMONSTRATION: I-2

TOOLS, EQUIPMENT, AND MATERIALS: (TM 2 from Unit 1, Lesson 1)

Service station hoist system  
Car

STEPS OF PROCEDURE:

- I. Survey and identify components and instrumentation of demonstration hoist system.
  - A. Air compressor and compression stages
    1. One-stage compressor
    2. Two-stage compressor
  - B. Motor
    1. Type of motor
    2. Horsepower and rpm rating
  - C. Air receiver tank
    1. Size or capacity
    2. Maximum pressure rating
  - D. Control and safety instrumentation
    1. Check valve
    2. Pressure relief and/or safety valve
    3. Control and/or stop valve(s)
    4. Filter-regulator-lubricator unit

- E. Air line
- F. Hoisting or lifting cylinders and safety devices

## II. Operation

### A. Hoisting or lifting

1. Position car in hoist system
2. Check car for stability and balance
  - a. Open inlet valve to let compressed air from receiver tank into cylinder.
  - b. Lift car 4 to 6 inches above ground and check stability and balance of car.
3. Continue to let compressed air from receiver tank into cylinder.
4. Lift slowly to the desired elevation.
5. Stop lifting and secure or engage safety mechanism to keep car in position.

### B. Observations - read pressure gage on the compressor to determine the pressure in the system.

### C. Lowering

1. Disengage safety device.
2. Open drain valve to let air out of the system.
3. —Lower car slowly.

## III. Have instructor check work on:

- A. Identification of basic components
- B. Operating procedures
- C. Safety measures or precautions.



LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT I : INTRODUCTION TO PNEUMATICS

DEMONSTRATION: I-2

**INTERACTION ITEMS:**

1. Discuss why a check valve is installed between the compressor and air receiver tank.
2. Discuss why a safety (pressure relief) valve is installed in the air receiver tank.
3. The system uses both oil and air. Discuss the purpose of the oil.

**CLASSROOM, LABORATORY, SHOP, OR OTHER ACTIVITIES:**

1. Review Operating Principles of Service Station Hoist using TM 2 (Unit I, Lesson Plan 1).

LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT I : INTRODUCTION TO PNEUMATICS

DEMONSTRATION: I-2

EVALUATION ITEMS:

The student has satisfactorily:

- I. Identified the basic components and instrumentation of the hoist system.
- II. Operated the hoist system.
- III. Practiced safety precautions and measures while operating the system.

Yes \_\_\_\_\_ No \_\_\_\_\_

\_\_\_\_\_  
Instructor's Signature  
(Verifying satisfactory completion)

\_\_\_\_\_  
Date

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT II : FUNDAMENTALS AND PHYSICAL LAWS

SCOPE OF UNIT:

After the completion of this unit, the student should be able to restate the fundamental physical laws applicable to pneumatics. The student should be able to use Pascal's law in transmission, intensification, and reduction of force in pneumatic systems and use Boyle's Law and Charles' Law to perceive the behavior of compressible fluids as the pressure, volume and/or temperature changes. The student should be able to explain work, power, and energy. This knowledge will be evidenced by scoring 85 percent on the evaluation items.

INFORMATION TOPIC: II-1

FUNDAMENTALS AND PHYSICAL LAWS  
(Lesson Title)

LESSON OBJECTIVES - THE STUDENT SHOULD BE ABLE TO:

1. Define common pneumatic terms.
2. Calculate pressure given force and area.
3. State Pascal's law.
4. Use Pascal's law in transmission, intensification, and reduction of force in pneumatic and hydraulic systems.
5. Convert absolute pressure to gage pressure and vice versa.
6. Convert absolute temperature to Fahrenheit temperature and vice versa.
7. State Boyle's law and calculate pressure and volume of compressible fluid (gas).
8. State Charles' law and calculate temperature and volume of compressible fluid.
9. Combine gas laws (Boyle's and Charles' laws) and calculate temperature, pressure, and volume of compressible fluid.
10. Define and calculate work, power, and energy.
11. Discuss the law of conservation of energy.

SUPPLEMENTARY TEACHING/LEARNING ITEMS:

1. TM 1: Pressure Determination
2. TM 2: Pascal's Law - Force-Pressure-Area Relationship
3. TM 3: Absolute and Gage Pressure in psi
4. TM 4: Determination of Absolute Temperature
5. TM 5: Boyle's Law
6. TM 6: Charles' Law
7. TM 7: Determination of Work and Power
8. TM 8: Change of State and Form of Energy

### INFORMATIONAL ASSIGNMENT: (Student)

Study the outline on the following pages prior to class time and be ready to discuss.

Pease, Dudley A. Basic Fluid Power. Englewood Cliffs, NJ: Prentice Hall, Inc., 1967, Chaps. 1 and II.

### REFERENCES: (Instructor's Additional Information)

Stewart, Harry L. Pneumatics and Hydraulics. 3rd ed. Indianapolis, IN: Theodore Audel and Co., 1978, Chap. 2.

Industrial Pneumatic Technology. Bulletin No. 0275-B1. Cleveland, OH: Parker Hannafin Corp., 1980, Chap. 2.

### INTRODUCTION:

Although their specific applications will be treated in subsequent lessons, the fundamentals and physical laws which are pertinent to pneumatics will be presented in this lesson.



LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT II : FUNDAMENTALS AND PHYSICAL LAWS

INFORMATION TOPIC: II-1

OUTLINE: (Key Points)

I. Terms and definitions

- A. **Pressure** - a force exerted at right angles over surface area divided by the area of its application (the force should act at right angles to the area)
- B. **Absolute pressure** - pressure measurement or reading above zero or perfect vacuum
- C. **Perfect vacuum** - a space without any gas molecules or a space at absolute zero pressure
- D. **Atmospheric pressure** - the pressure exerted by the atmosphere at any specific location
- E. **Vacuum** - any space with pressure below atmospheric pressure
- F. **Gage pressure** - pressure measurement or reading with atmospheric pressure taken as zero (reference) pressure
- G. **Energy** - the ability or the capacity to do work
- H. **Potential energy** - stored energy of an object by the virtue of its position
- I. **Kinetic energy** - energy of an object by the virtue of its motion

II. Calculation of pressure (TM 1)

- A. Determine force applied over an area.
- B. Determine the area of the surface to which the force is applied.
- C. Divide the force by the area of application to determine the pressure over the area. Pressure is normally measured in pounds per square inch (psi). Therefore, force should be measured in pounds and the area in square inches.

Example: If the force applied over an area is 1000 pounds and the area of application is 4 square inches, then pressure over the area is 250 psi.

- III. Pascal's law - pressure of a confined fluid (liquid or gas) is transmitted undiminished in every direction at right angles (perpendicular) to the surface of the confining container (TM 2).

Example: If the pressure of the air in the container is 100 psi, then a pressure of 100 psi is acting in every direction at right angles to the surface of the container.

- IV. Calculation of force transmitted from a pneumatic system (TM 2)

- A. Determine the pressure of the pneumatic system.
- B. Determine the area from which the force is transmitted.
- C. Force transmitted is equal to pressure times area.

Example: The force transmitted from piston B = 5000 lbs.  
The force transmitted from piston C = 100 lbs.

(NOTE: This is a typical example of the application of Pascal's law for transmittance, intensification, and reduction of forces by pneumatic systems.)

- V. Determination of absolute and gage pressure (TM 3)

- A. Under normal conditions, at sea level, atmospheric pressure is equal to approximately 14.7 psi.
- B. Absolute pressure is equal to gage pressure plus atmospheric pressure.

Example: If the gage pressure of a pneumatic system is 150 pounds per square inch (psig), then the absolute pressure is 164.7 pounds per square inch absolute (psia).

- C. Gage pressure is equal to absolute pressure minus atmospheric pressure.

Example: If the absolute pressure is 10 psia, then the gage pressure is -4.7 psig.

(NOTE: Absolute pressures cannot be less than zero (negative), while gage pressure can be less than zero (negative) such as in a vacuum.)

- VI. Absolute temperature (TM 4)

- A. In English units, absolute temperature is measured in degrees Rankine ( $^{\circ}\text{R}$ ) and is equal to 460 plus temperature in degrees Fahrenheit ( $^{\circ}\text{F}$ ).

Example: If the temperature of the air is  $70^{\circ}\text{F}$ , then the absolute temperature is  $530^{\circ}\text{R}$ .

- VII. Boyle's law - keeping the temperature the same, a gaseous mass can be compressed and its final compressed volume is inversely proportional to the absolute pressure. That is, the volume decreases as the pressure increases and volume increases as the pressure decreases. Mathematically Boyle's law can be stated as: (TM 5)

$$\begin{aligned} (\text{Absolute pressure} \times \text{volume})_{\text{initial}} &= (\text{Absolute pressure} \times \text{volume})_{\text{final}} \\ (P_1 V_1) &= (P_2 V_2) \end{aligned}$$

Where  $P_1$  = Initial pressure  
 $V_1$  = Initial volume  
 $P_2$  = Final pressure  
 $V_2$  = Final volume

Example: If an air tank containing 100 cubic feet at 20 psia is compressed to 40 psia at constant temperature, its final compressed volume is 50 cubic feet.

- VIII. Charles' law - keeping the pressure constant, the volume of a gaseous mass is directly proportional to the absolute temperature. That is, volume increases as temperature increases and volume decreases as the temperature decreases. Mathematically, Charles' law can be expressed as (TM 6)

$$\begin{aligned} \left[ \frac{\text{Volume}}{\text{absolute temperature}} \right]_{\text{initial}} &= \left[ \frac{\text{Volume}}{\text{absolute temperature}} \right]_{\text{final}} \\ \frac{V_1}{T_1} &= \frac{V_2}{T_2} \end{aligned}$$

Where  $V_1$  = Initial volume  
 $T_1$  = Initial temperature  
 $V_2$  = Final volume  
 $T_2$  = Final temperature

Example: At a constant pressure, an air balloon holds 10 cubic feet of air at 400°R. Assuming the balloon can inflate, the volume of the air at 1200°R is 11.6 cubic feet.

- IX. Combination of gas laws - Boyle's law and Charles' law can be combined to give the relationship between the absolute pressure, absolute temperature and volume of a gaseous mass as

$$\begin{aligned} \frac{\text{absolute pressure} \times \text{volume}}{\text{absolute temperature}}_{\text{initial}} &= \frac{\text{absolute pressure} \times \text{volume}}{\text{absolute temperature}}_{\text{final}} \\ \frac{P_1 V_1}{T_1} &= \frac{P_2 V_2}{T_2} \end{aligned}$$

Example: If a closed tank holds 300 cubic feet at 14.7 psig and 60°F is heated to 120°F, the final is 32.8 psia.

(NOTE: DO NOT forget to change both pressure and temperature to absolute values.)

X. Work, power, and energy (TM 7)

- A. Work - force times the distance traveled by the force, normally expressed in foot-pounds (ft-lb). Therefore, the distance is measured in feet and the force in pounds.

Example: The work done by 100 lb. force to lift (move) a weight to position 2 which is 10 feet above (distance) position 1 is 1000 foot-pounds (1000 ft-lb).

- B. Power - work done in a unit of time, equal to work divided by the time required to perform the work. Although the unit of time is usually taken as one second, one minute and one hour are also used. (TM 7)

Example: If the 1000 ft-lb (see above) is done in 4 seconds, the power is 250 ft-lb per second (fps).

- C. Energy - the capacity or the ability of an object to do work by the virtue of its position (potential) or motion (kinetic).

(NOTE: Machines are rated in horsepower (hp) where one horsepower has been arbitrarily set to equal 550 ft-lb/sec (fps).

XI. Law of conservation of energy - energy can neither be created nor destroyed, but it can change its state and form.

A. Energy can be found in two states (TM 7)

1. Potential energy - which is equal to the weight of an object (W) times the height or elevation (h) to which the object is raised or lifted and is equal to the work required to lift an object from position 1 to position 2.

$$\text{Potential Energy} = (\text{Weight of object}) \times (\text{height lifted})$$
$$P.E. = Wh$$

Example: In the example above, the 100 lbs. object is lifted 10 feet to position 2 from position 1. Calculate the potential energy of the object at position 2.

$$\text{Potential Energy} = 100 \text{ lbs.} \times 10 \text{ ft.} = 1000 \text{ ft-lbs.}$$

2. Kinetic energy - which is equal to one-half of the mass of an object (m) times the velocity of the object (V) squared.

(NOTE: Where mass is defined as the weight (W) of an object divided by the acceleration due to gravity (g) which is equal to 32.2 ft./sec.<sup>2</sup>)

$$M = \frac{W}{g}$$



$$\text{Kinetic Energy} = 0.5 (\text{mass of object}) \times (\text{Velocity}) \times (\text{Velocity})$$
$$\text{K.E.} = 0.5(mV^2)$$

Example: An object whose mass is 15.5 slug is moving at a constant velocity of 2.5 ft/sec. Determine the kinetic energy of the object.

$$\text{Kinetic energy} = 0.5(15.5)(2.5^2) = 48.44 \text{ ft-lb.}$$

(NOTE: A slug is a unit of mass that is accelerated at the rate of one foot per second squared when acted upon by a force of one pound.)

B. Forms of Energy (TM 8)

1. Electrical
2. Mechanical
3. Heat
4. Light
5. Sound
6. Chemical
7. Magnetic

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT II : FUNDAMENTALS AND PHYSICAL LAWS

INFORMATION TOPIC: II-1

#### INTERACTION ITEMS

1. What physical laws are applied in operating a simple bicycle hand pump? Discuss how they are applied.
2. Meteorologists use helium-filled balloons to carry weather recording instruments high into the atmosphere. However, people argue that these balloons burst in the atmosphere. What possibly could happen to these balloons and why?
3. A hydroelectric power plant in your area uses the potential energy of water behind a dam to generate electricity. Trace and list the changes in energy form and/or state the energy goes through before it reaches your home or your school.

CLASSROOM, LABORATORY, SHOP, OR OTHER ACTIVITIES:

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT II : FUNDAMENTALS AND PHYSICAL LAWS

INFORMATION TOPIC: II-1

#### EVALUATION ITEMS

1. Match the terms on the right with the correct definition on the left.

- |        |                                                                                          |     |                      |
|--------|------------------------------------------------------------------------------------------|-----|----------------------|
| ___ a. | Force exerted at right angles over a surface area divided by the area of its application | 1.  | Work                 |
| ___ b. | The ability or the capacity to do work                                                   | 2.  | Power                |
| ___ c. | A space without any gas molecules or a space at absolute zero pressure                   | 3.  | Kinetic energy       |
| ___ d. | Force times the distance traveled by the force                                           | 4.  | Potential energy     |
| ___ e. | Pressure measurement or reading above zero or perfect vacuum                             | 5.  | Energy               |
| ___ f. | Any space whose pressure is below atmospheric pressure                                   | 6.  | Pressure             |
| ___ g. | Pressure measurement or reading taken at zero (reference) pressure                       | 7.  | Absolute pressure    |
| ___ h. | Energy of a moving object                                                                | 8.  | Gage pressure        |
| ___ i. | Work done in a unit of time                                                              | 9.  | Vacuum               |
| ___ j. | Stored energy of an object by the virtue of its position                                 | 10. | Perfect vacuum       |
| ___ k. | The pressure exerted by the atmosphere at any specific location                          | 11. | Atmospheric pressure |

2. Calculate the pressure if:
- a. Force = 1000 lbs., Area = 25 sq. in.
  - b. Force = 800 lbs., Area = 20 sq. in.
  - c. Force = 800 lbs., Area = 10 sq. in.

3. State Pascal's law.

4. Calculate the force applied on an area if
- a. Pressure = 100 psi, Area = 5 sq. in.
  - b. Pressure = 500 psi., Area = 1 sq. in.
  - c. Pressure = 500 psi, Area = 5 sq. in.

5. Perform the necessary conversion

- a. 50 psig = \_\_\_\_\_ psia
- b. 50 psia = \_\_\_\_\_ psig
- c. -14.7 psig = \_\_\_\_\_ psia

6. Perform the necessary conversion

- a.  $100^{\circ}\text{F} = \text{_____}^{\circ}\text{R}$  (absolute degrees Rankine)
- b.  $-20^{\circ}\text{F} = \text{_____}^{\circ}\text{R}$  (absolute degrees Rankine)
- c.  $500^{\circ}\text{R} = \text{_____}^{\circ}\text{F}$  (degrees Fahrenheit)



7. a. State Boyle's law
- b. Assuming the temperature is kept the same, determine the initial volume if the initial gage pressure is 50 psig, the final gage pressure is 114.7 psig and the final volume is 40 cubic feet. (Hint: remember to convert gage pressures to absolute pressures.)
8. a. State Charles' law.
- b. A container with 100 cubic feet of air at  $32^{\circ}\text{F}$  is heated to  $212^{\circ}\text{F}$ . If the container is allowed to expand to keep the pressure the same, what is the volume of the air at  $212^{\circ}\text{F}$ ? (Hint: remember to convert  $^{\circ}\text{F}$  to  $^{\circ}\text{R}$ , absolute temperature.)
9. If a closed tank holds 300 cubic feet at 14.7 psig and  $60^{\circ}\text{F}$  is heated to  $120^{\circ}\text{F}$ , what is the final psia?
10. A man carried a 50 lb. box and climbed a flight of stairs whose vertical distance is 20 feet in 5 seconds. How much work has he done and how much horsepower was used in the box?
11. a. State the law of conservation of energy.
- b. Name and define two states of energy.
- 1)
- 2)

c. List six forms of energy.

1)

2)

3)

4)

5)

6)

d. The water stored behind Hoover dam is used to generate electricity. Trace and list the changes in state and/or form experienced by the energy when it reaches the microwave oven of an energy customer.

12 Write "True" or "False" beside each statement below.

\_\_\_ a. Work and power are identical.

\_\_\_ b. Heat lost from an engine is lost forever.

\_\_\_ c. The volume of a gaseous mass is directly proportional to temperature means that as the temperature decreases, the volume decreases.

\_\_\_ d. The volume of a gaseous mass is inversely proportional means that as the pressure increases the volume increases.

\_\_\_ e. In using Boyle's law and Charles' law, it is not necessary to change the pressure and temperature to absolute values.

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT II : FUNDAMENTALS AND PHYSICAL LAWS

INFORMATION TOPIC: II-1

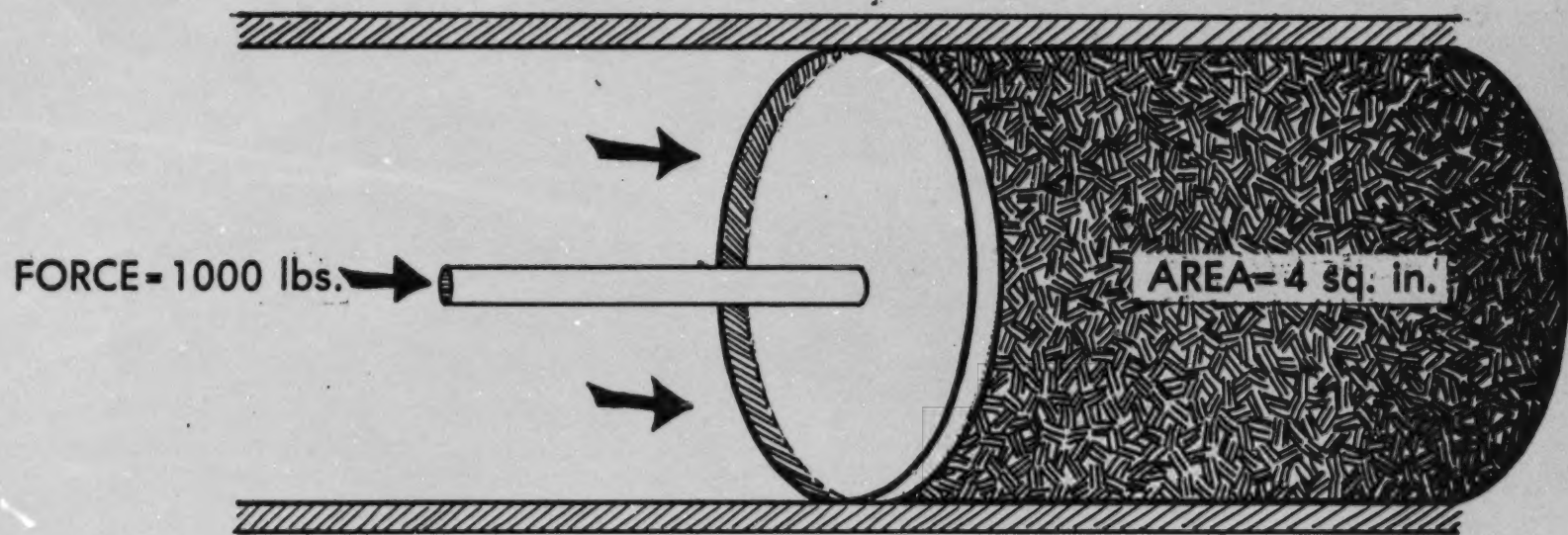
ANSWERS TO EVALUATION ITEMS

1.
  - a. 6
  - b. 5
  - c. 10
  - d. 1
  - e. 7
  - f. 9
  - g. 8
  - h. 3
  - i. 2
  - j. 4
  - k. 11
2.
  - a. 40 psi
  - b. 40 psi
  - c. 80 psi
3. The pressure of a confined fluid (liquid or gas) is transmitted in every direction at right angles to the surface of the confining container.
4.
  - a. 500 lbs.
  - b. 500 lbs.
  - c. 2500 lbs.
5.
  - a.  $560^{\circ}\text{R}$
  - b.  $440^{\circ}\text{R}$
  - c.  $40^{\circ}\text{F}$
6.
  - a. 64.7 psia
  - b. 35.3 psig
  - c. 0.0 psia
7.
  - a. Keeping the temperature the same, a gaseous mass can be compressed and its final volume is inversely proportional to the absolute pressure.
  - b. 80 cubic feet

8. a. Keeping the pressure constant, the volume of a gaseous mass is directly proportional to the absolute temperature.  
b. 136.6 cubic feet
9. 32.8 psia
10. Work done = 1000 ft-lbs.  
Power = 200 ft-lbs/sec. (fps)
11. a. Energy can neither be created nor destroyed but can change its state and/or form.  
b. 1) Potential energy  
2) Kinetic energy  
c. Any six of the following:  
1) electrical  
2) mechanical  
3) heat  
4) light  
5) sound  
6) chemical energy  
7) magnetic  
d. It should include  
1) Potential energy of water behind dam is converted to kinetic energy in the penstock (pipe) that leads to the turbine.  
2) The kinetic energy of the running water in the penstock is converted to mechanical energy by the turbine.  
3) The mechanical energy of the turbine turns the generator to generate electricity.  
4) The electrical energy (electricity) is transported by power lines to the microwave oven which converts the electricity to light energy.  
5) The light energy of the microwave oven is converted to heat energy to cook food or boil water.
12. a. False  
b. False  
c. True  
d. False  
e. False

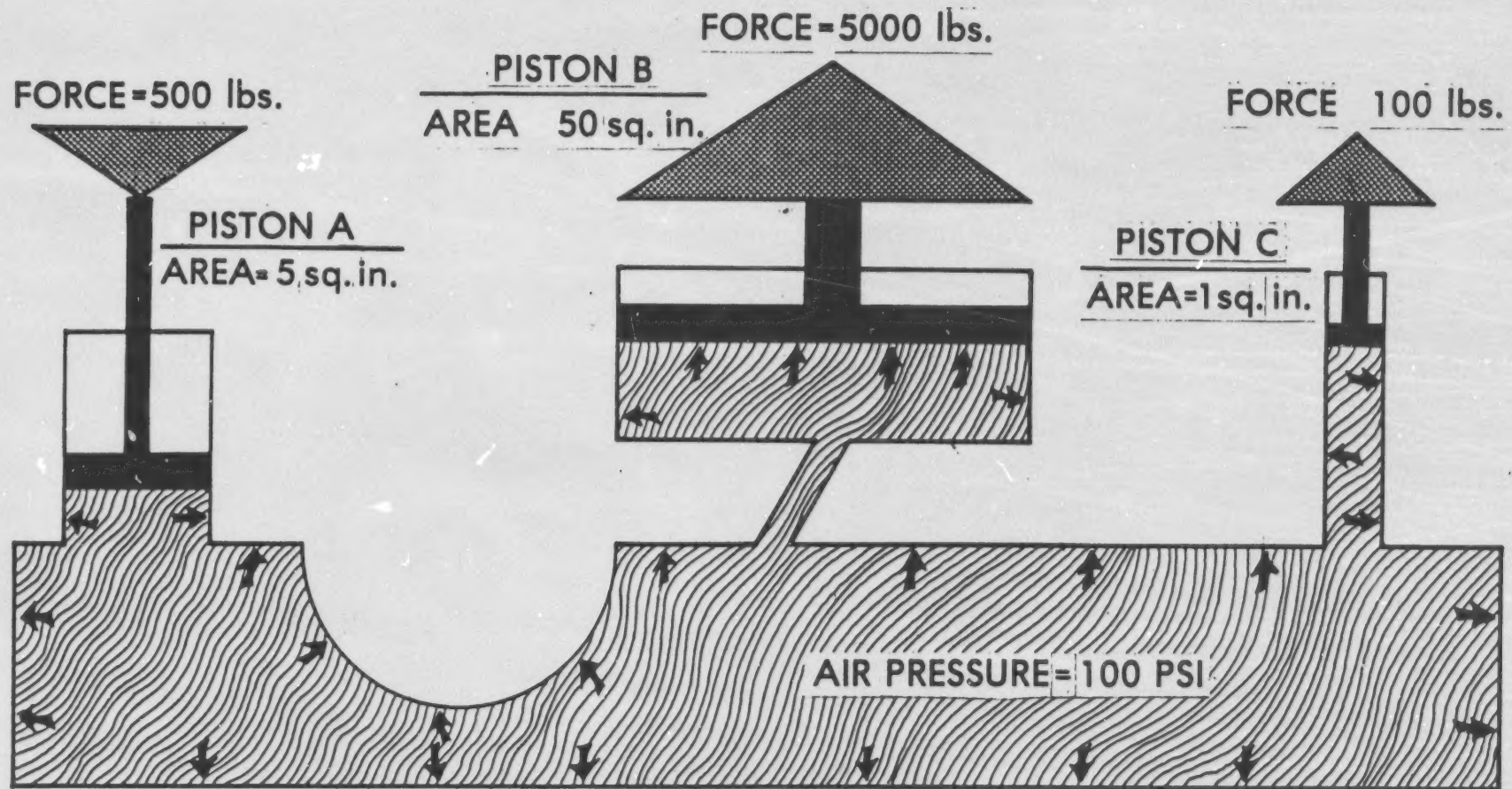


## PRESSURE DETERMINATION

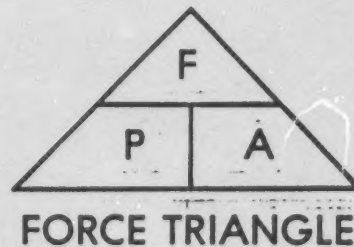


$$\text{PRESSURE} = \frac{\text{Force}}{\text{Area}} = \frac{1000 \text{ lbs.}}{4 \text{ sq. in.}} = 250 \text{ PSI}$$

# PASCAL'S LAW: FORCE - PRESSURE - AREA RELATIONSHIP



FORCE = F  
PRESSURE = P  
AREA = A

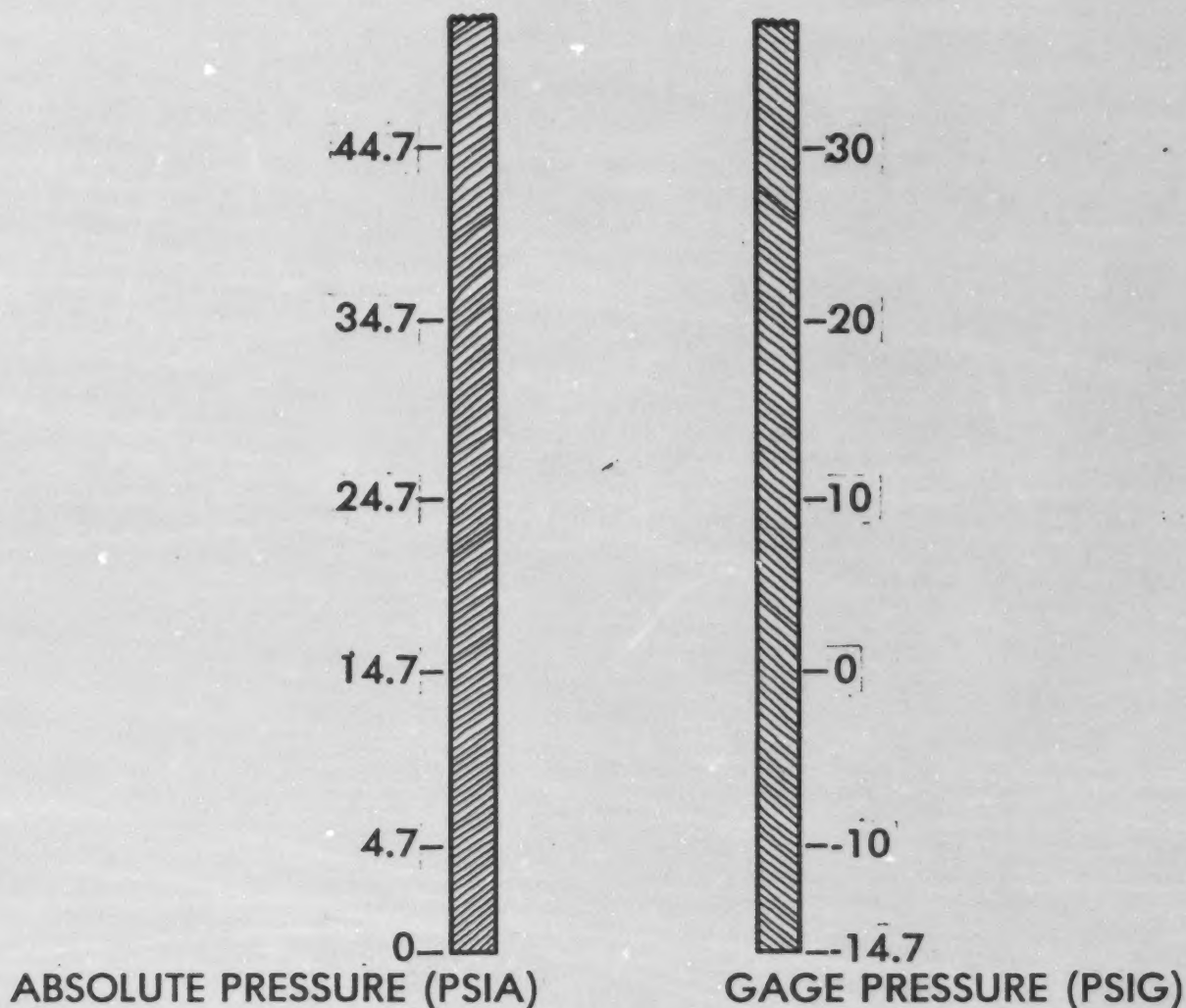


$$F = P \times A$$

$$P = \frac{F}{A}$$

$$A = \frac{F}{P}$$

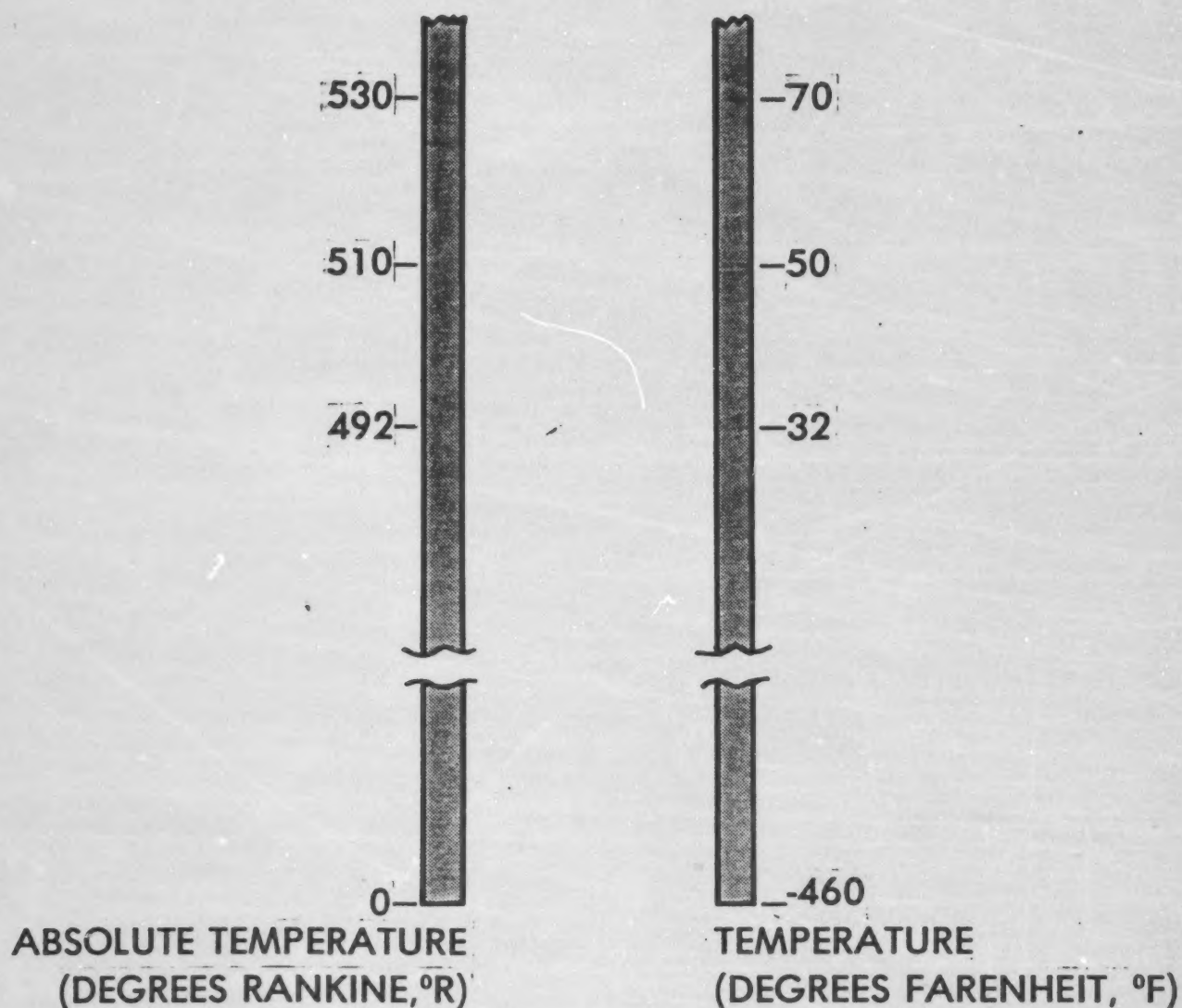
# ABSOLUTE AND GAGE PRESSURE IN PSI <sup>TM-3</sup>



$$\text{ABSOLUTE PRESSURE} = \text{PRESSURE GAGE} + 14.7$$

$$\text{GAGE PRESSURE} = \text{ABSOLUTE PRESSURE} - 14.7$$

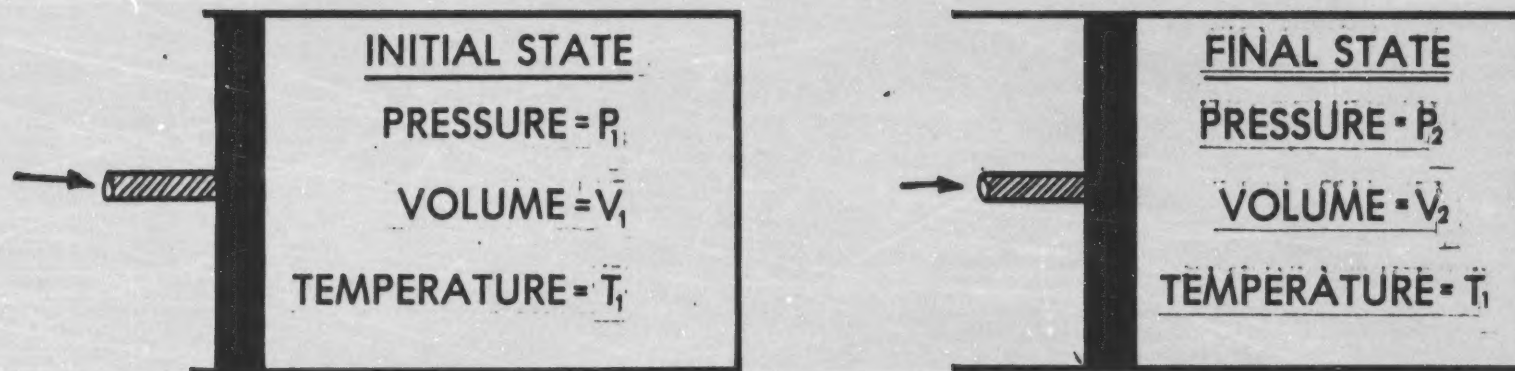
## DETERMINATION OF ABSOLUTE TEMPERATURE



$$\text{ABSOLUTE TEMPERATURE (°R)} = \text{TEMPERATURE °F} + 460$$



## BOYLE'S LAW



INITIAL PRESSURE  $\times$  INITIAL VOLUME = FINAL PRESSURE  $\times$  FINAL VOLUME

$$(P_1 V_1 = P_2 V_2)$$

NOTE:

USE ABSOLUTE PRESSURE

TEMPERATURE REMAINS THE SAME

# CHARLES' LAW

## INITIAL STATE

TEMPERATURE =  $T_1$

VOLUME =  $V_1$

PRESSURE =  $P_1$

## FINAL STATE

TEMPERATURE =  $T_2$

VOLUME =  $V_2$

PRESSURE =  $P_1$

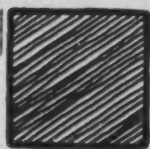
$$\frac{\text{INITIAL VOLUME}}{\text{INITIAL TEMPERATURE}} = \frac{\text{FINAL VOLUME}}{\text{FINAL TEMPERATURE}}$$
$$\left( \frac{V_1}{T_1} = \frac{V_2}{T_2} \right)$$

NOTE:

USE ABSOLUTE TEMPERATURE  
PRESSURE REMAINS THE SAME

# DETERMINATION OF WORK AND POWER TM-7

POSITION 1



FORCE = 100lbs.

LIFTED 10 FEET  
IN 4 SECONDS

POSITION 2



$$\text{WORK} = \text{FORCE} \times \text{DISTANCE}$$

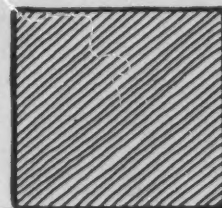
$$\text{WORK} = 100\text{lbs.} \times 10 \text{ ft.} = 1000 \text{ ft.-lbs.}$$

$$\text{POWER} = \frac{\text{WORK}}{\text{TIME}} = \frac{1000 \text{ lbs.-ft.}}{4 \text{ sec.}} = 250 \text{ ft.-lbs./sec.}$$

POSITION 1



POSITION 2



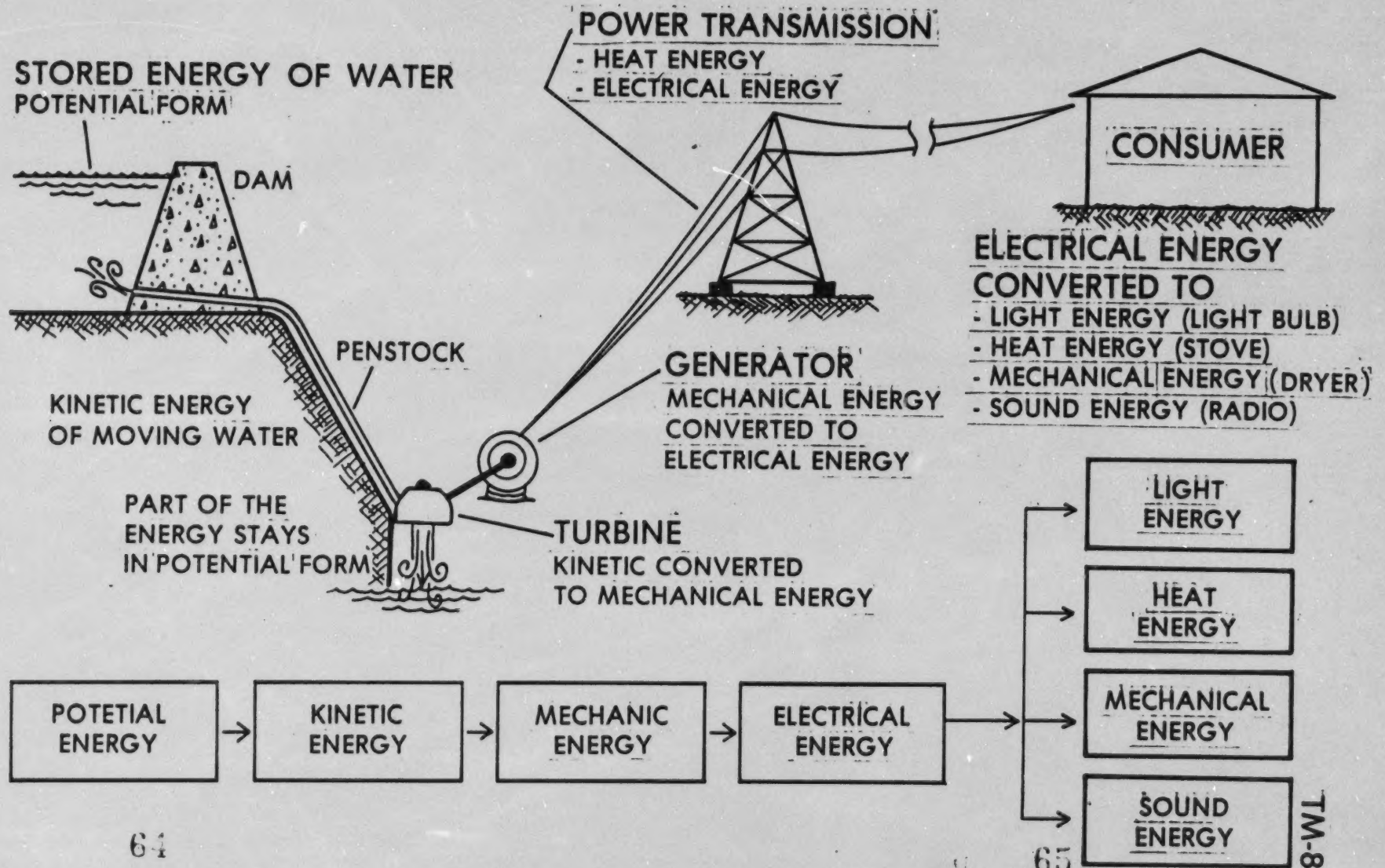
MOVED 100 FEET IN 40 SECONDS

$$\text{WORK} = \text{FORCE} \times \text{DISTANCE}$$

$$\text{WORK} = 100\text{lbs.} \times 100\text{ft.} = 10,000 \text{ ft.-lbs.}$$

$$\text{POWER} = \frac{\text{WORK}}{\text{TIME}} = \frac{10,000 \text{ ft.-lbs.}}{40 \text{ sec.}} = 250 \text{ ft.-lbs./sec.}$$

# CHANGE OF STATE AND FORM OF ENERGY





LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT III : AIR COMPRESSORS

SCOPE OF UNIT:

After the completion of this unit, the student should be able to name and classify the types of air compressors and identify the basic components of each type. The student should be able to outline and discuss the operating principles of each type of compressor and state the methods of compressing or increasing the pressure or the potential energy of compressed air. The student should be able to state factors that influence the installation and safe operation of compressors. The student should be able to disassemble, clean, and reassemble a simple bicycle hand pump. The student should be able to name and explain the physical laws which apply to a compressor. This knowledge will be evidenced by correctly performing the procedures outlined in the demonstration lesson and by scoring 85 percent on the evaluation items.

INFORMATION TOPIC: III-1

POSITIVE DISPLACEMENT (PRESSURE) COMPRESSORS  
(Lesson Title)

LESSON OBJECTIVES - THE STUDENT SHOULD BE ABLE TO:

1. Define compressor.
2. Define positive displacement (pressure) compressor.
3. Classify and describe two types of positive displacement compressors.
4. Identify a one-stage reciprocating piston compressor, its components, and its operating principles.
5. Identify a two-stage reciprocating piston compressor, its components, and its operating principles.
6. Identify a sliding vane rotary compressor and its components, and describe its operating principles.
7. Identify a lobed-rotor compressor and its components, and describe its operating principles.
8. Demonstrate an understanding of dry and oil-flooded helical (screw) compressors by stating the difference between them.

SUPPLEMENTARY TEACHING/LEARNING ITEMS:

1. TM 1: Single-Stage Reciprocating Piston Compressor
2. TM 2: Two-Stage Reciprocating Piston Compressor
3. TM 3: Sliding Vane Rotary Compressor
4. TM 4: Lobed-Rotor Compressor
5. TM 5: Helical (Screw) Compressor

**INFORMATIONAL ASSIGNMENT: (Student)**

Stewart, L. Harry. Pneumatics and Hydraulics. 3rd ed. Indianapolis, IN: Theodore Audel and Co., 1978.

Industrial Pneumatic Technology, Bulletin 0275-B1. Parker Hannifin Corporation, 1980.

**REFERENCES: (Instructor's Additional Information)**

Pease, A. Dudley. Basic Fluid Power. Englewood Cliffs, NJ: Prentice-Hall Inc., 1967.

**INTRODUCTION:**

Before a gaseous mass can be utilized to do useful work, it must be compressed and stored under high pressure.

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT III : AIR COMPRESSORS

INFORMATION TOPIC: III-1

OUTLINE: (Key Points)

- I. Compressor - a device which compresses or increases the air pressure for immediate or future use.
- II. Positive displacement (pressure-type) compressor - a compressor which compresses or increases the pressure of air by changing the volume of air contained in confined spaces.
- III. Types of positive displacement compressors
  - A. Reciprocating piston type - a compressor which increases the air pressure by reciprocating motion of piston
    1. Single-stage reciprocating piston type compresses the air in one stage.
    2. Multi-stage reciprocating piston type compresses the air in two or more compression stages.
  - B. Rotary compressor - a compressor which increases the air pressure by means of a component which rotates in a circular motion.
    1. Sliding vane rotor compressor
    2. Lobed-rotor compressors
    3. Helical (screw) compressor
      - a. Dry helical compressor
      - b. Oil-flooded compressor
- IV. Reciprocating single-stage compressor (TM 1)
  - A. Components
    1. Inlet valve
    2. Outlet valve
    3. Cylinder

4. Reciprocating piston
5. Piston rod
6. Drive shaft

B. Operation

1. Intake stroke
  - a. Inlet valve is open.
  - b. Outlet valve is closed.
  - c. Piston moves down.
  - d. Air pressure in cylinder is less than atmospheric pressure.
  - e. Air enters cylinder through inlet valve.
2. Compression stroke
  - a. Inlet valve is closed.
  - b. Outlet valve is open.
  - c. Piston moves up.
  - d. Air in cylinder is compressed.
  - e. High pressure air leaves cylinder through outlet valve.

V. Reciprocating two-stage compressor (TM 2)

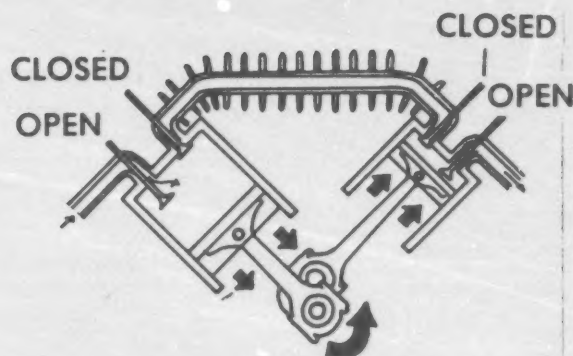
A. Components

1. First and second stage inlet valves
2. First and second stage outlet valves
3. First and second stage cylinders
4. First and second stage pistons
5. First and second stage piston rods
6. Common drive shaft

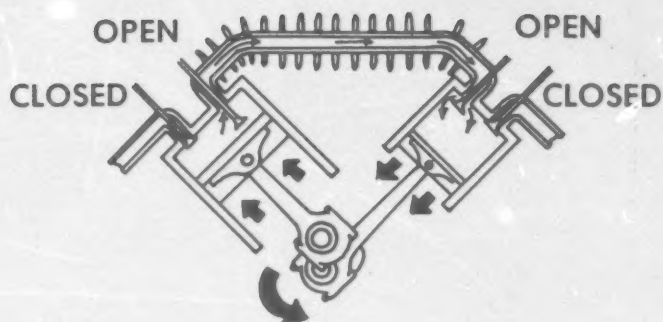


B. Operation

1. Simultaneous first stage intake stroke and second stage compression stroke.



2. Simultaneous first stage compression stroke and second stage intake stroke.



(NOTE: 1) Intercooler between Stage 1 and Stage 2 is to cool the hot compressed air from Stage 1; and 2) In stage one, there can be a number of cylinders acting simultaneously.)

C. Comparison between first stage and second stage

1. Valves opening and closing are opposite to each other.
2. Motion of pistons is opposite to each other.
3. Stage 2 has smaller cylinder and piston sizes.

VI. Sliding vane rotary compressor (TM 3)

A. Components

1. Casing or housing
2. Rotor which is positioned off center of casing
3. Sliding vanes
4. Drive shaft

B. Operation

1. Intake or suction
  - a. Rotor rotates about the drive shaft.
  - b. Sliding vanes are thrown out of rotor by centrifugal force.
  - c. Air is trapped between the vanes and casing.
2. Discharge or compression
  - a. Sliding vanes are pushed into rotor by casing.
  - b. Decreasing volume between vanes compresses the air .
  - c. Compressed air exits through the outlet.

VII. Lobed-rotor compressor (TM 4)

A. Components

1. Casing or housing
2. Two lobes
3. Two parallel drive shafts

B. Operation

1. Two lobes rotate in opposite directions.

2. Air is drawn into the housing and trapped between the housing and lobes.
3. Trapped air is compressed and exits through the outlet.

VIII. Helical (screw) compressors (TM 5)

- A. Dry helical compressor - rotating helical screws do not mesh on rotation.
- B. Oil-flooded helical compressor - rotating helical screws mesh on rotation.
- C. Operation - similar to sliding vane or lobed-rotor compressors.

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT III : AIR COMPRESSORS

INFORMATION TOPIC: III-1

INTERACTION ITEMS:

1. Why is the compressed air from first stage compression hot and why does it need to be cooled before it enters the second stage compression? (Hint: Boyle's law can be used in your discussion.)
2. Other than for cooling the compressed air, is there any other reason why you need an intercooler between first-stage and second-stage compression?
3. Is there any advantage to having a common drive shaft in a two-stage reciprocating compressor?
4. Besides helping to compress the air, what purpose does the oil have in oil-flooded helical screws?
5. Discuss why the air that leaves the second-stage compression is at a higher pressure than that of first-stage.

CLASSROOM, LABORATORY, SHOP, OR OTHER ACTIVITIES:



LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT III : AIR COMPRESSORS

INFORMATION TOPIC: III-1

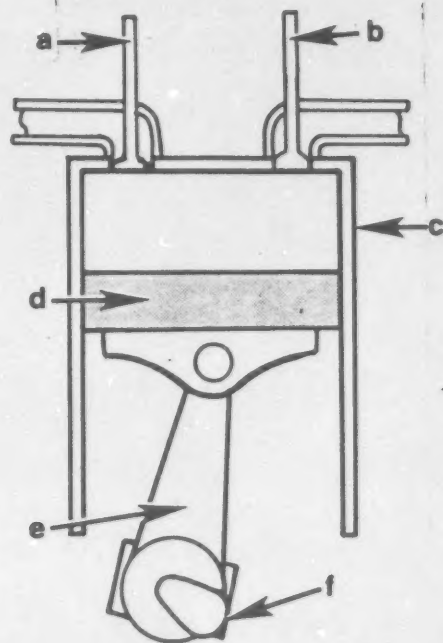
EVALUATION ITEMS:

1. Define compressor.
2. Describe a positive displacement (pressure-type) compressor.
3. Classify and describe two types of positive displacement compressors.

- 4.1. Identification: Identify the type of compressor shown below and write the name of each component in the space next to the appropriate letter.

Type of Compressor: \_\_\_\_\_

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_
- f. \_\_\_\_\_



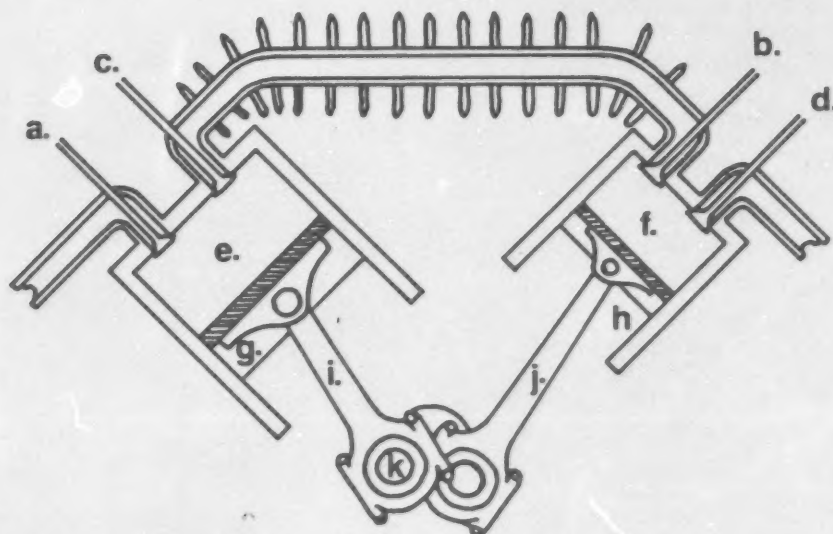
4.2. In the space provided, write true or false for each of these statements pertaining to the operating principles of a single-stage reciprocating piston compressor.

- \_\_\_ a. Inlet valve is open during the compression stroke.
- \_\_\_ b. Outlet valve is open during the intake stroke.
- \_\_\_ c. During the compression stroke, the air pressure inside the cylinder is higher than atmospheric pressure.
- \_\_\_ d. During the intake stroke, the air pressure inside the cylinder is less than atmospheric pressure.

5.1. Identification: Identify the type of compressor shown below and write the name of each component in the space next to the appropriate letter.

Type of Compressor: \_\_\_\_\_

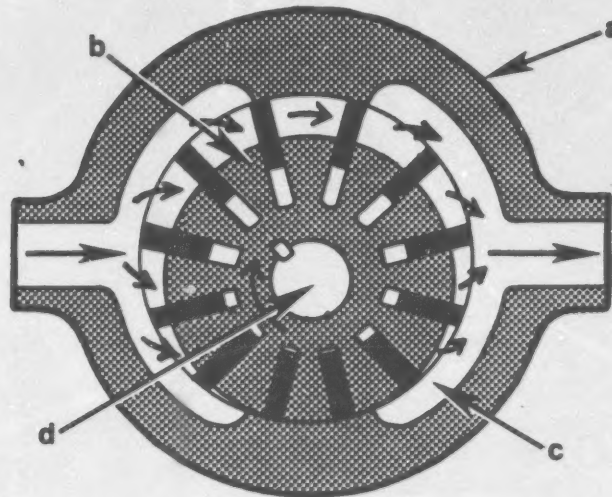
- |          |          |
|----------|----------|
| a. _____ | g. _____ |
| b. _____ | h. _____ |
| c. _____ | i. _____ |
| d. _____ | j. _____ |
| e. _____ | k. _____ |
| f. _____ |          |



5.2. In the space provided, write true or false for each of these statements pertaining to the operating principles of a two-stage reciprocating piston compressor.

- \_\_\_ a. During the compression stroke of the first stage air enters the second stage.
- \_\_\_ b. First-stage and second-stage inlet valves open and close at the same time.
- \_\_\_ c. When air enters the first-stage cylinder, air leaves from the second-stage cylinder.
- \_\_\_ d. Piston and cylinder sizes are equal in both stages of compression.

6. Identification: Identify the type of compressor shown below and write the name of each component in the space next to the appropriate letter. Indicate by arrows the direction of motion of air and compressor moving parts.



Type of Compressor: \_\_\_\_\_

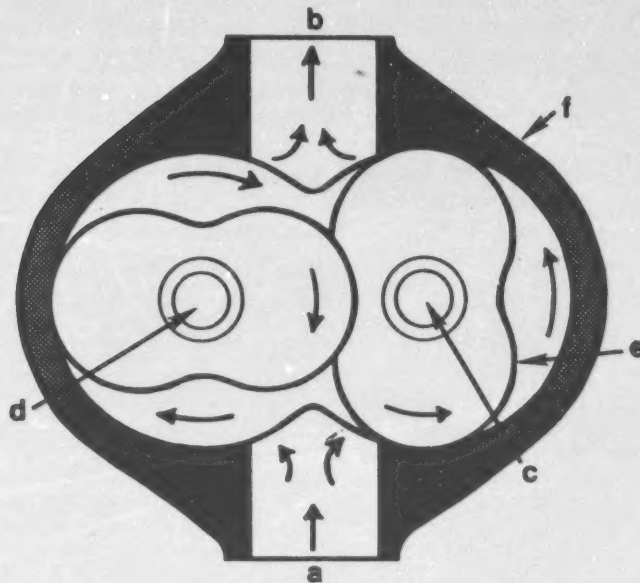
a. \_\_\_\_\_

c. \_\_\_\_\_

b. \_\_\_\_\_

d. \_\_\_\_\_

7. Identification: Identify the type of compressor shown below and write the name of each component in the space next to the appropriate letter. Indicate by arrows the direction of motion of air and compressor moving parts.



Type of Compressor: \_\_\_\_\_

a. \_\_\_\_\_

b. \_\_\_\_\_

c. \_\_\_\_\_

d. \_\_\_\_\_

e. \_\_\_\_\_

f. \_\_\_\_\_

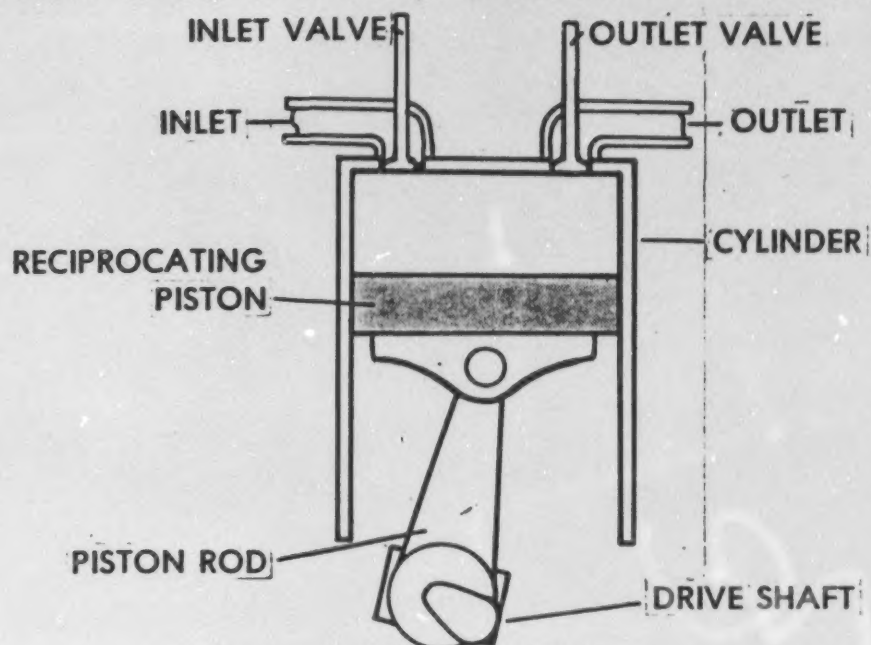
8. State the difference between a dry helical (screw) compressor and an oil-flooded helical (screw) compressor.



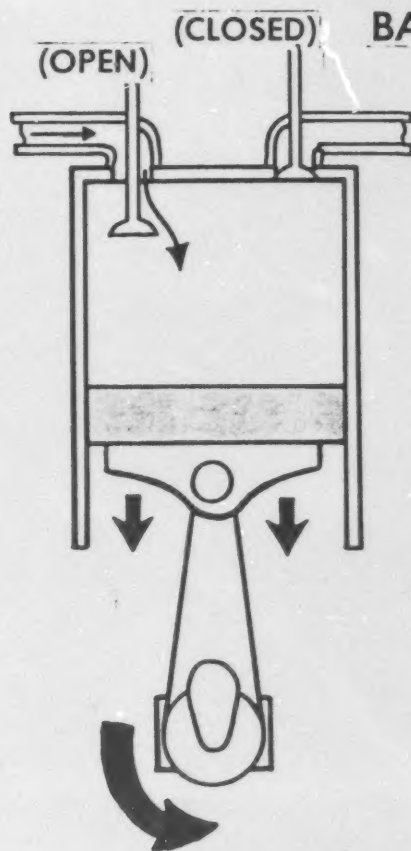
- 5.2.
  - a. True
  - b. False
  - c. True
  - d. False
  
- 6. Type of compressor: sliding vane rotary compressor
  - a. Casing or housing
  - b. Rotor which is positioned off center of casing
  - c. Sliding vanes
  - d. Drive shaft
  
- 7. Type of compressor: lobed-rotor
  - a. Inlet
  - b. Outlet
  - c. Drive shaft
  - d. Drive shaft
  - e. Lobe
  - f. Housing
  
- 8. In a dry helical (screw) compressor the gears do not mesh on rotation, while in an oil flooded compressor the gears mesh on rotation with oil required as lubricant.

# SINGLE-STAGE RECIPROCATING PISTON COMPRESSOR

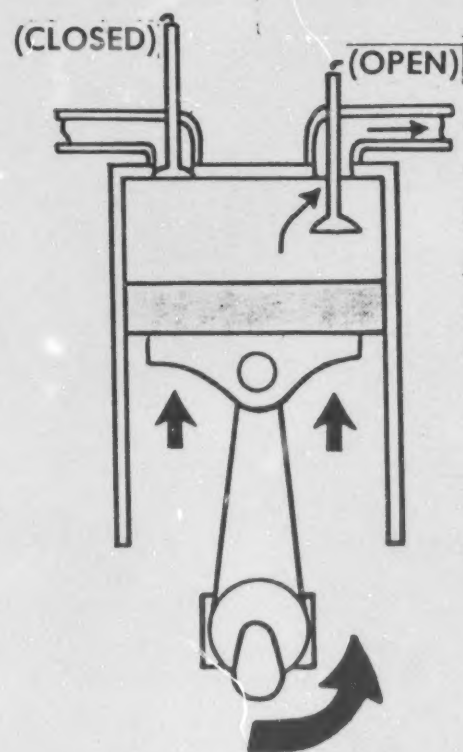
TM-1



## BASIC COMPONENTS



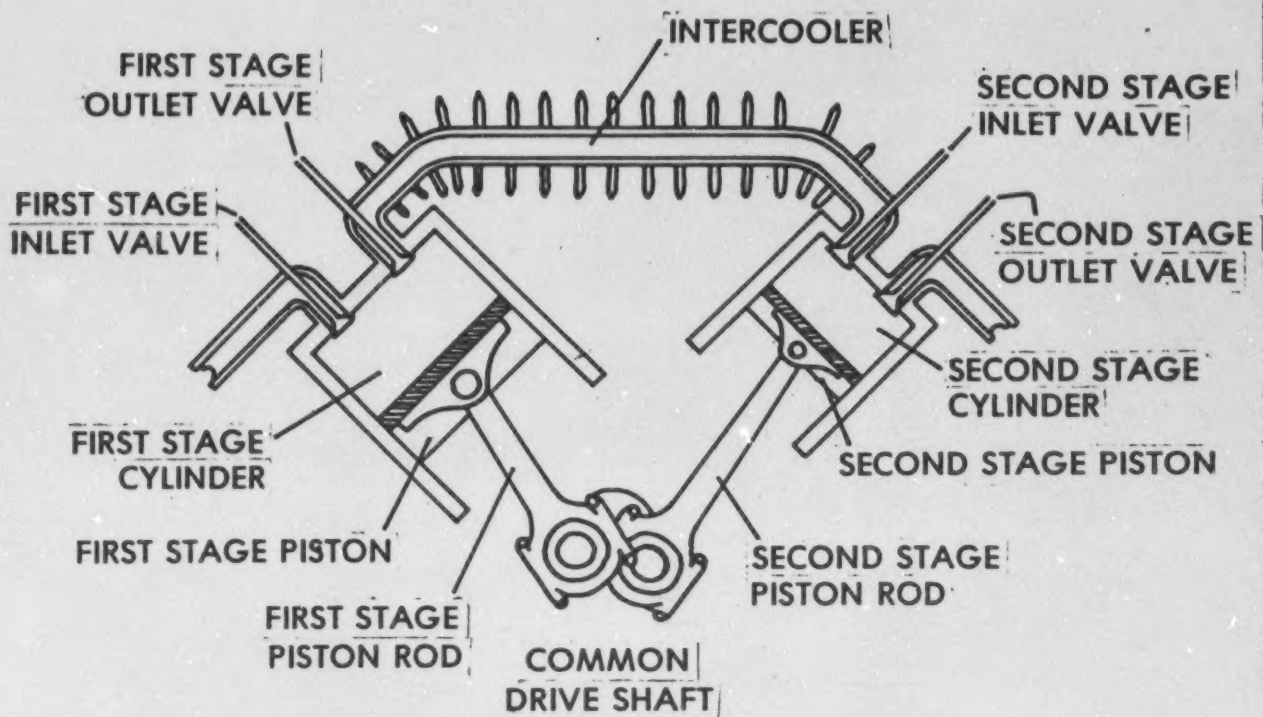
INTAKE STROKE



COMPRESSION STROKE

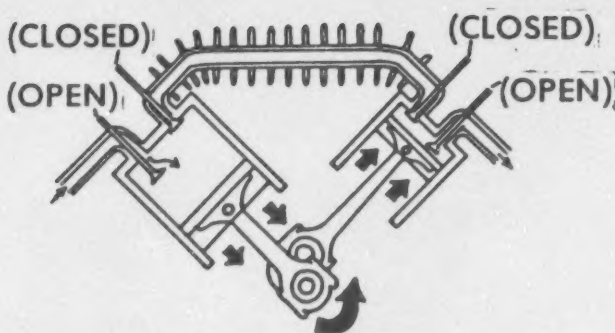
# TWO-STAGE RECIPROCATING PISTON COMPRESSOR

TM-2



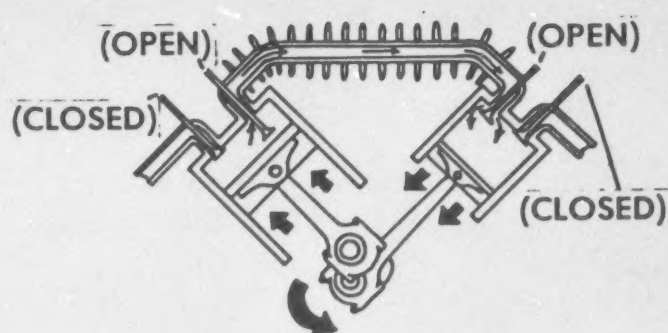
## BASIC COMPONENTS

Fig. 1



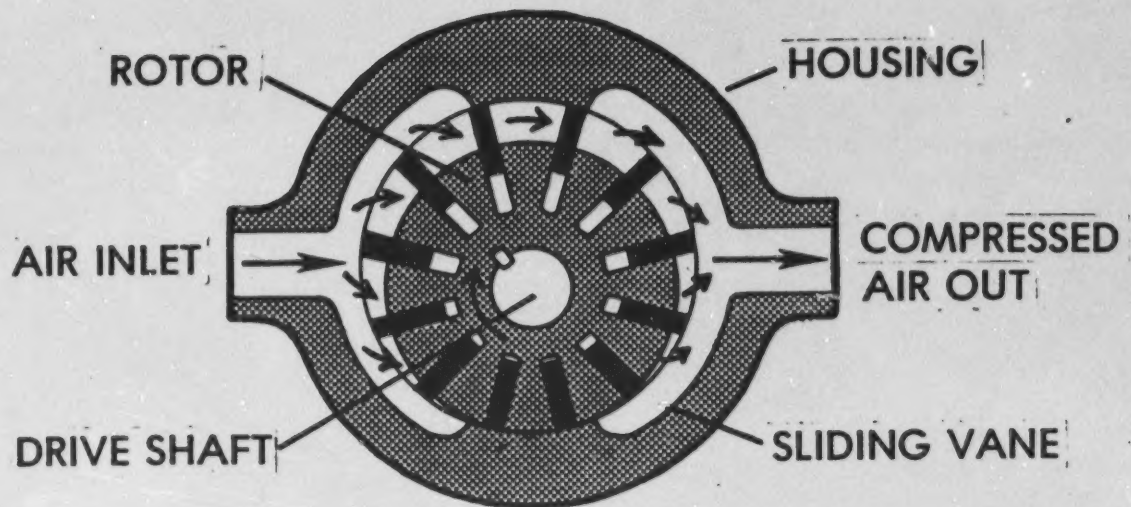
FIRST STAGE INTAKE AND SECOND  
STAGE COMPRESSION STROKE

Fig. 2

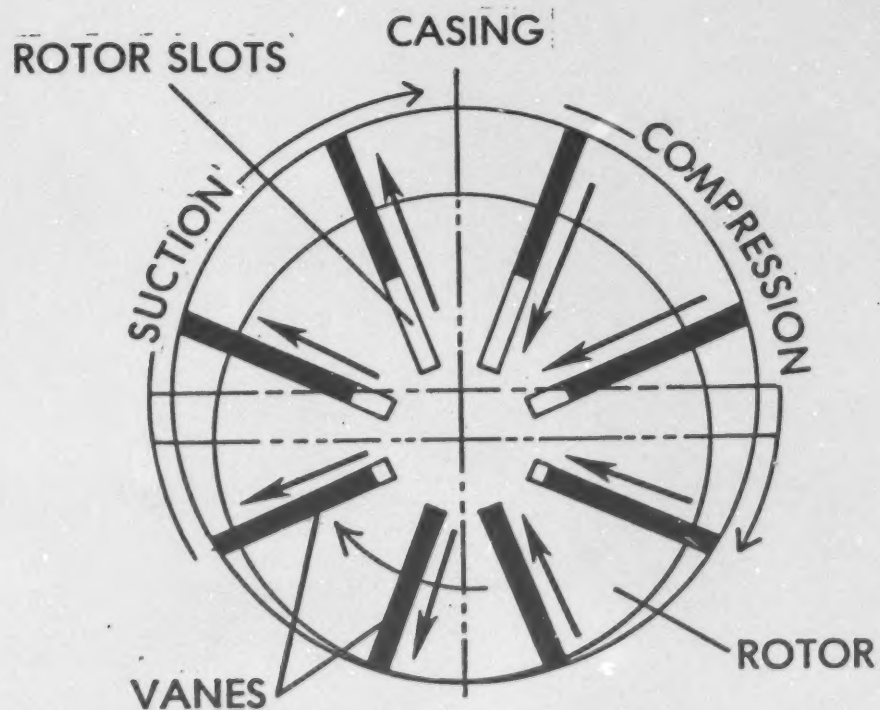


FIRST STAGE COMPRESSION AND  
SECOND STAGE INTAKE STROKE

# SLIDING VANE ROTARY COMPRESSOR TM-3



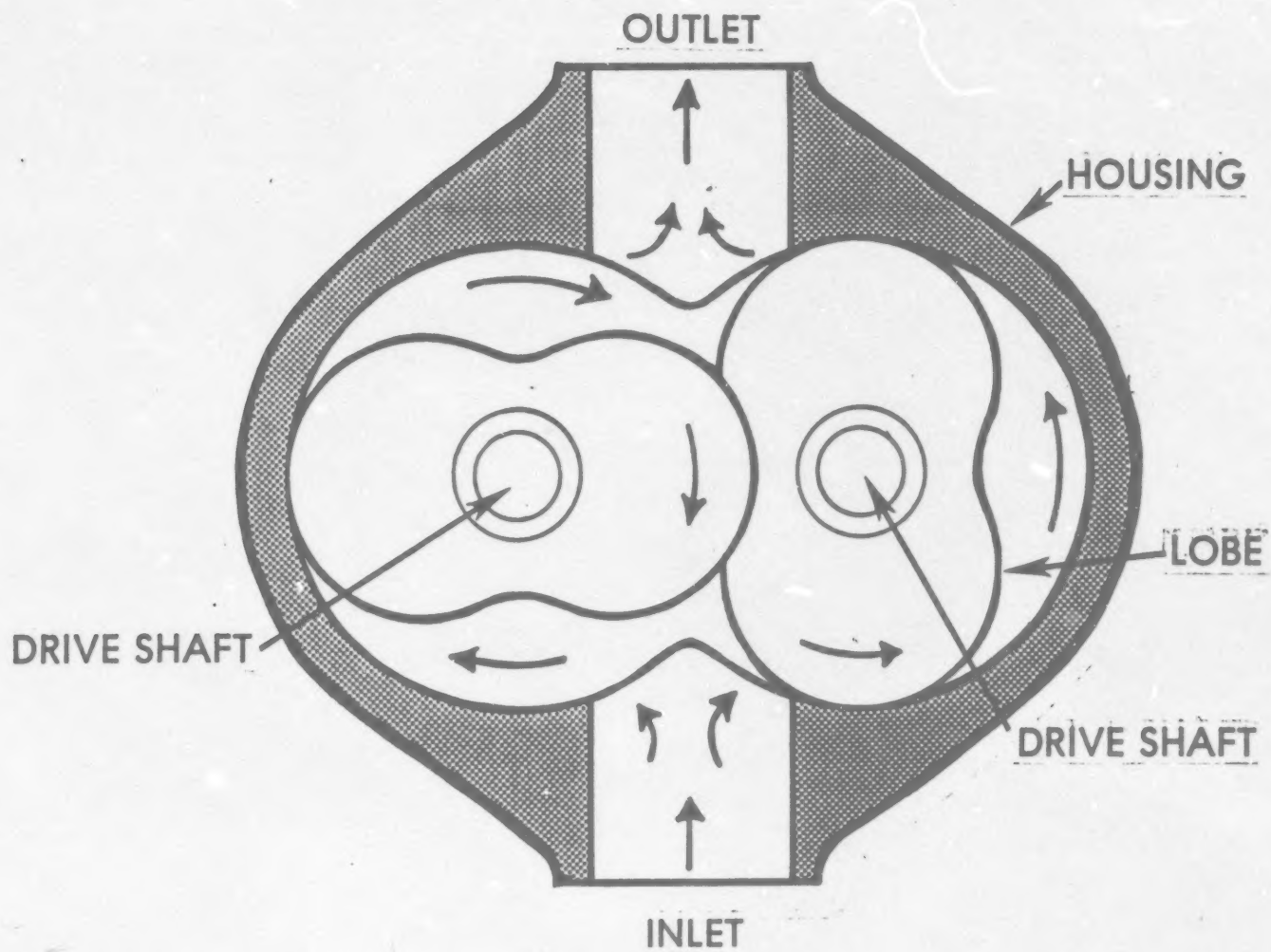
BASIC COMPONENTS



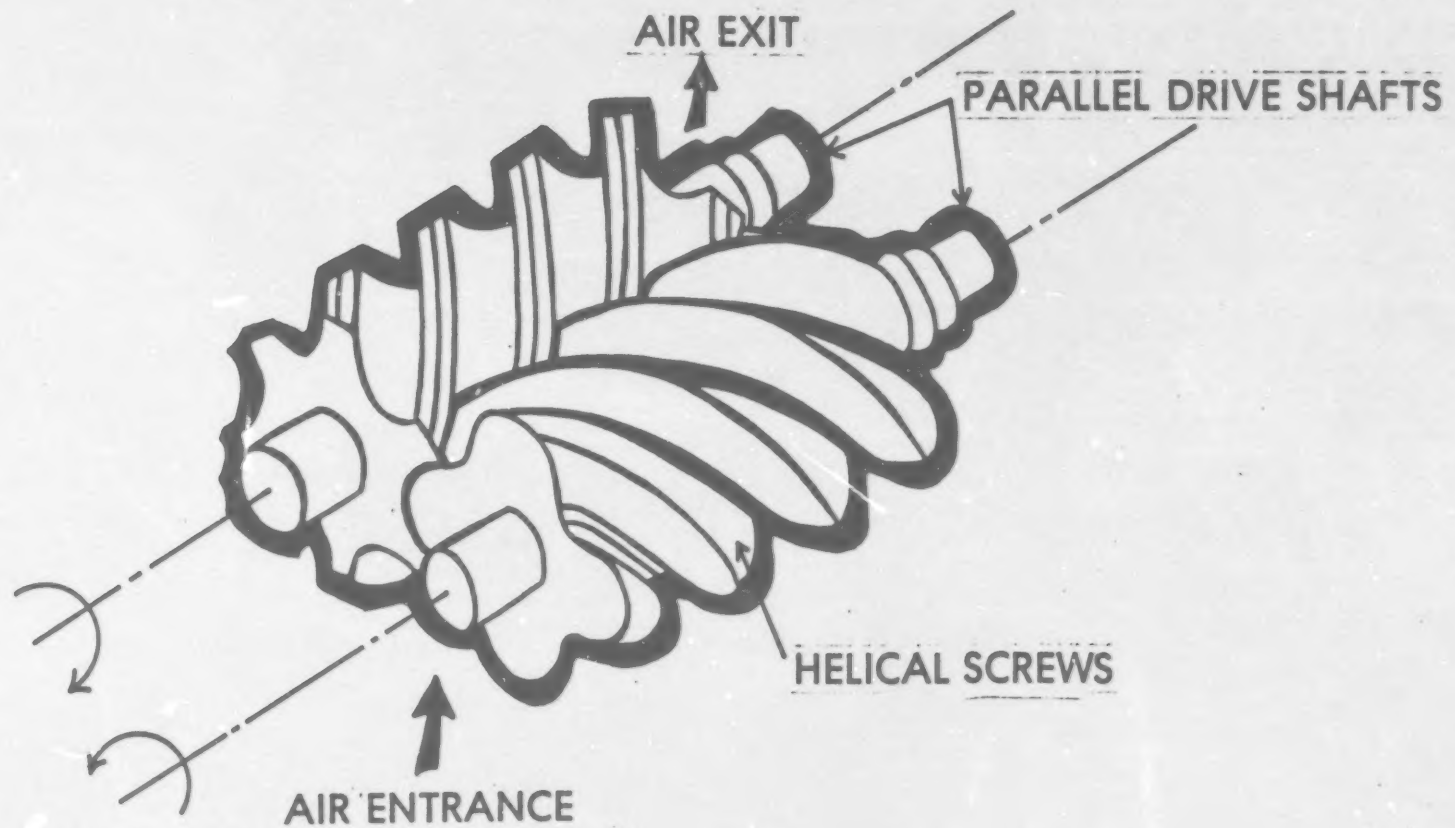
RELATIVE MOTION OF PARTS



# LOBED-ROTOR COMPRESSOR



# HELICAL SCREW COMPRESSOR



LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT III : AIR COMPRESSORS

SCOPE OF UNIT:

After the completion of this unit, the student should be able to name and classify the types of air compressors and identify the basic components of each type. The student should be able to outline and discuss the operating principles of each type of compressor and state the methods of compressing or increasing the pressure or the potential energy of compressed air. The student should be able to state factors that influence the installation and safe operation of compressors. The student should be able to disassemble, clean, and reassemble a simple bicycle hand pump. The student should be able to name and explain the physical laws which apply to a compressor. This knowledge will be evidenced by correctly performing the procedures outlined in the demonstration lesson and by scoring 85 percent on the evaluation items.

INFORMATION TOPIC: III-2

VELOCITY (DYNAMIC) COMPRESSORS  
(Lesson Title)

LESSON OBJECTIVES - THE STUDENT SHOULD BE ABLE TO:

1. Define velocity (dynamic) compressors.
2. Name and describe two types of velocity (dynamic) compressors.
3. Identify a radial-centrifugal compressor and its components, and discuss its operating principles.
4. Identify an axial-centrifugal compressor and its components, and discuss its operating principles.
5. Recognize operating and output differences between radial- and axial-centrifugal compressors.

SUPPLEMENTARY TEACHING/LEARNING ITEMS:

1. TM 1: Radial-centrifugal Compressor
2. TM 2: Axial-centrifugal Compressor

**INFORMATIONAL ASSIGNMENT: (Student)**

Stewart, L. Harry. Pneumatics and Hydraulics. 3rd ed. Indianapolis, IN: Theodore Audel and Co., 1978.

Industrial Pneumatic Technology, Bulletin 0275-B1. Parker Hannifin Corporation, 1980.

**REFERENCES: (Instructor's Additional Information)**

Pease, A. Dudley. Basic Fluid Power. Englewood Cliffs, NJ: Prentice-Hall Inc., 1967.

**INTRODUCTION:**

Before a gaseous mass can be utilized to do useful work, it must be compressed and stored under high pressure.



LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT III : AIR COMPRESSORS

INFORMATION TOPIC: III-2

OUTLINE: (Key Points)

- I. Velocity (dynamic) compressor - a compressor which increases the air pressure by imparting kinetic energy (velocity) to an air mass and then converting it to pressure.
- II. Types of velocity (dynamic) compressors
  - A. Radial-centrifugal compressor
  - B. Axial-centrifugal compressor
- III. Radial-centrifugal compressor - a compressor in which the air to be compressed is radially accelerated by centrifugal force within the housing of the compressor. (TM 1)

(NOTE: Radial movement of air means that the air mass is directed to move at a right angle (perpendicular) to the axis or shaft of the radial-centrifugal compressor.)

A. Components

1. Casing or housing
2. Impellers - rotating blades attached to drive shaft
3. Diffusers
4. Drive shaft
5. Inlet
6. Outlet

B. Operation

1. Impellers rotate about the drive shaft.
2. Air enters the eye of the impellers.
3. Centrifugal force accelerates the air mass radially outward.

4. Accelerated air reaches diffusers where the air
  - a. Velocity decreases.
  - b. Kinetic energy is partly converted to pressure.
  - c. Is directed radial, enter the eye of the next row of impellers.

(NOTE: Steps 2 through 4 are repeated until the air leaves the compressor.)

IV. Axial-centrifugal compressor - a compressor in which the air to be compressed is axially (parallel to axis of compressor) accelerated by centrifugal force within the housing of the compressor (TM 2)

A. Components

1. Casing or housing
2. Impellers - rotating blades attached to drive shaft
3. Stationary vanes - to direct the flow axially
4. Drive shaft
5. Inlet
6. Outlet

B. Operation

1. Impellers rotate about the drive shaft.
2. Air enters through inlet.
3. Rotating motion of impellers accelerates air mass.
4. Both impellers and stationary vanes force air to accelerate axially.
5. Kinetic energy of accelerating air is converted to pressure partly on the exit (diffuser) and partly in the receiver tank.

(NOTE: In an axial-centrifugal compressor, the cross-sectional area decreases toward the outlet, or discharge side.)

V. Comparison of radial- and axial-centrifugal compressors

- A. For the same output capacity, axial compressors have a smaller diameter than radial.
- B. For the same output capacity, axial compressors need a higher speed (rpm) motor than radial.

- C. Axial compressors deliver at a constant flow rate; radial compressors deliver at a variable flowrate.
- D. The pressure output of axial compressors is variable; the pressure output of radial compressors is constant.

LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT III : AIR COMPRESSORS

INFORMATION TOPIC: III-2

INTERACTION ITEMS:

1. Taking into consideration that diffusers have increasing cross-sectional area towards the air exit, why does the pressure increase and the velocity decrease in the diffuser? (HINT: Use Bernoulli equation from your hydraulics course and Boyle's law.)
2. What is the advantage of having the cross-sectional area of an axial-centrifugal compressor decrease towards the exit?

CLASSROOM, LABORATORY, SHOP, OR OTHER ACTIVITIES:



LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT III : AIR COMPRESSORS

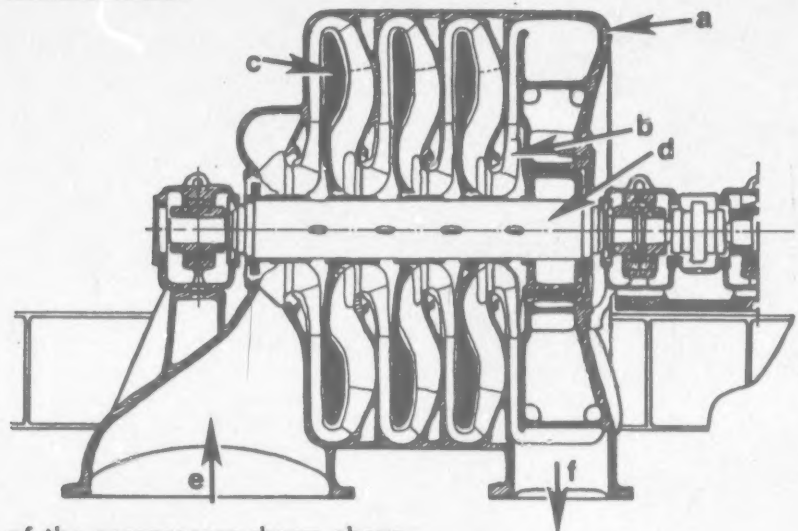
INFORMATION TOPIC: III-2

EVALUATION ITEMS:

1. Define velocity (dynamic) compressors.
2. Name and describe two types of velocity compressors.
  - a.
  - b.
- 3.1 Identification: Identify the type of compressor shown below and write the name of each component in the space next to the appropriate letter.

Type of Compressor: \_\_\_\_\_

- a.
- b.
- c.
- d.
- e.
- f.

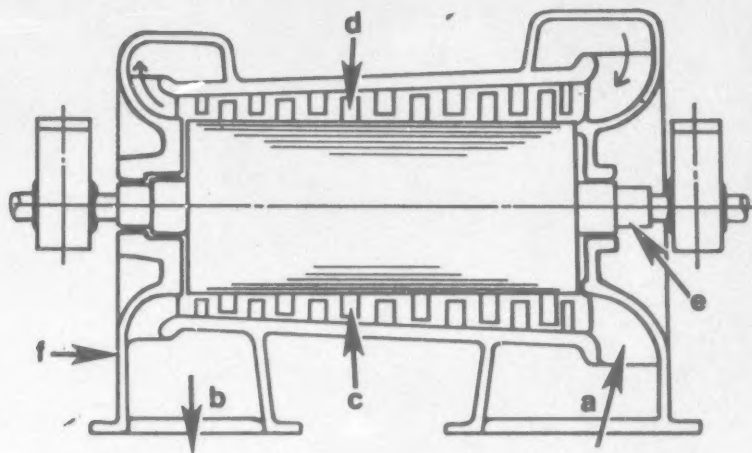


- 3.2 Discuss the operation of the compressor shown above.

- 4.1 Identification: Identify the type of compressor shown below and write the name of each component in the space next to the appropriate letter.

Type of Compressor: \_\_\_\_\_

- a.
- b.
- c.
- d.
- e.
- f.



- 4.2 Discuss the operating principles of the compressor shown above.

5. In the space provided, write true or false for each of the following statements.

- \_\_\_ a. Axial-centrifugal compressors deliver at variable flow rate.
- \_\_\_ b. Radial-centrifugal compressors deliver at variable pressure output.
- \_\_\_ c. Axial-centrifugal compressors deliver at variable pressure output.
- \_\_\_ d. Radial-centrifugal compressors deliver at variable pressure output.
- \_\_\_ e. For the same output capacity, axial compressors need a higher speed (rpm) motor than radial.

LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT III : AIR COMPRESSORS

INFORMATION TOPIC: III-2

ANSWERS TO EVALUATION ITEMS:

1. A compressor which increases the air pressure by imparting kinetic energy (velocity) to an air mass and then converting it to pressure.
2.
  - a. Radial-centrifugal compressor - a compressor in which the air to be compressed is radially accelerated by centrifugal force within the housing of the compressor
  - b. Axial-centrifugal compressor - a compressor in which the air to be compressed is axially (parallel to axis of compressor) accelerated by centrifugal force within the housing of the compressor
- 3.1. Radial-Centrifugal Compressor
  - a. Casing or housing
  - b. Impeller
  - c. Diffuser
  - d. Drive shaft
  - e. Inlet
  - f. Outlet
- 3.2. Discussion should include:
  - a. Impellers rotate about the drive shaft.
  - b. Air enters the eye of the impellers.
  - c. Centrifugal force accelerates the air mass radially outward.
  - d. Accelerated air reaches diffusers where the air
    - 1) Velocity decreases.
    - 2) Kinetic energy is partly converted to pressure.
    - 3) Is directed radially to enter the eye of the next row of impellers.
  - e. Steps a through d are repeated until the air leaves compressor.
- 4.1. Axial-Centrifugal Compressor
  - a. Inlet
  - b. Outlet
  - c. Impellers
  - d. Stationary vanes
  - e. Drive shaft
  - f. Housing or casing

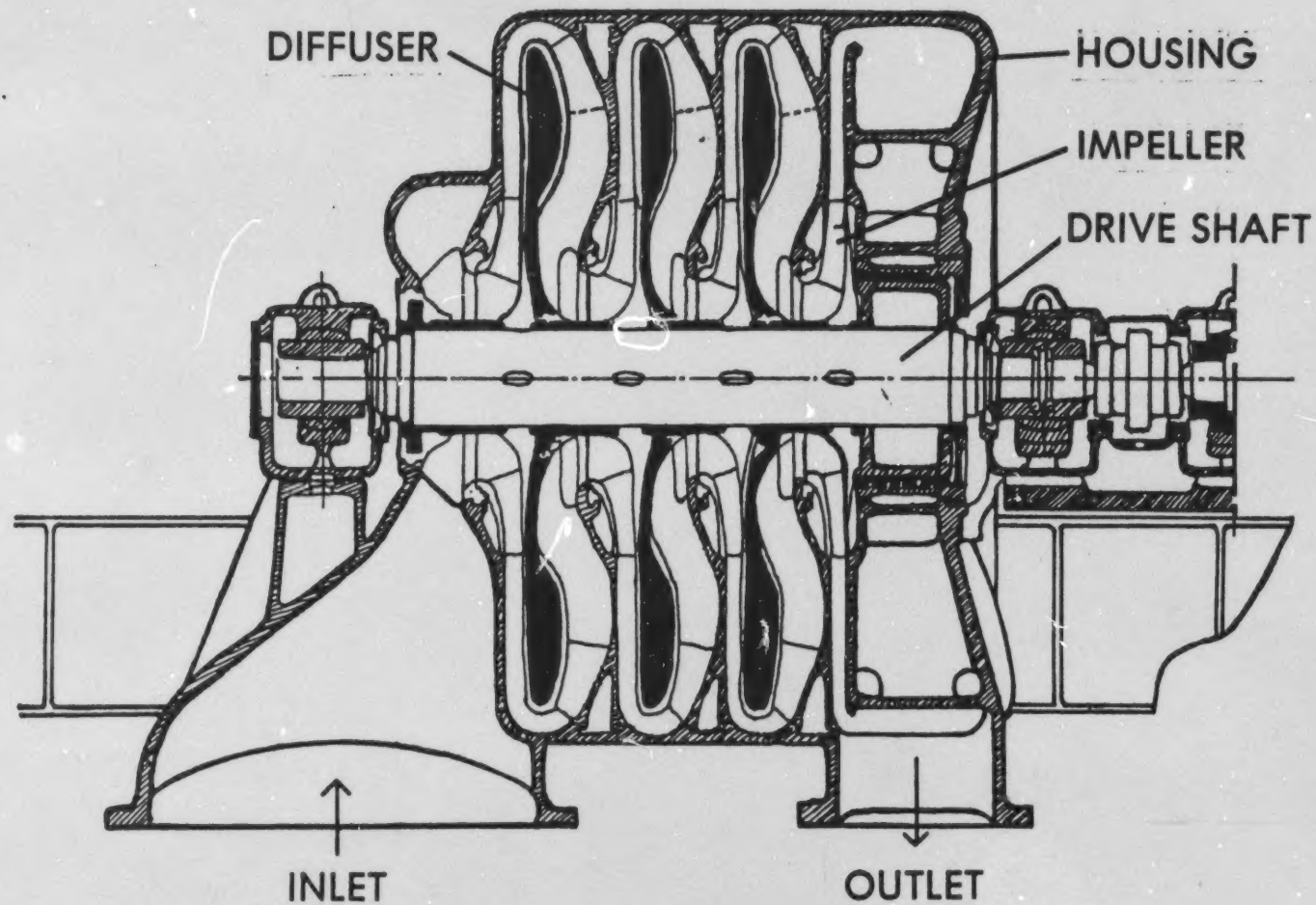
4.2 Discussion should include:

- a. Impellers rotate about the drive shaft.
- b. Air enters through inlet.
- c. Rotating motion of impellers accelerates air mass.
- d. Both impellers and stationary vanes force air to accelerate axially.
- e. Kinetic energy of accelerating air is converted to pressure partly on the exit (diffuser) and partly in the receiver tank.

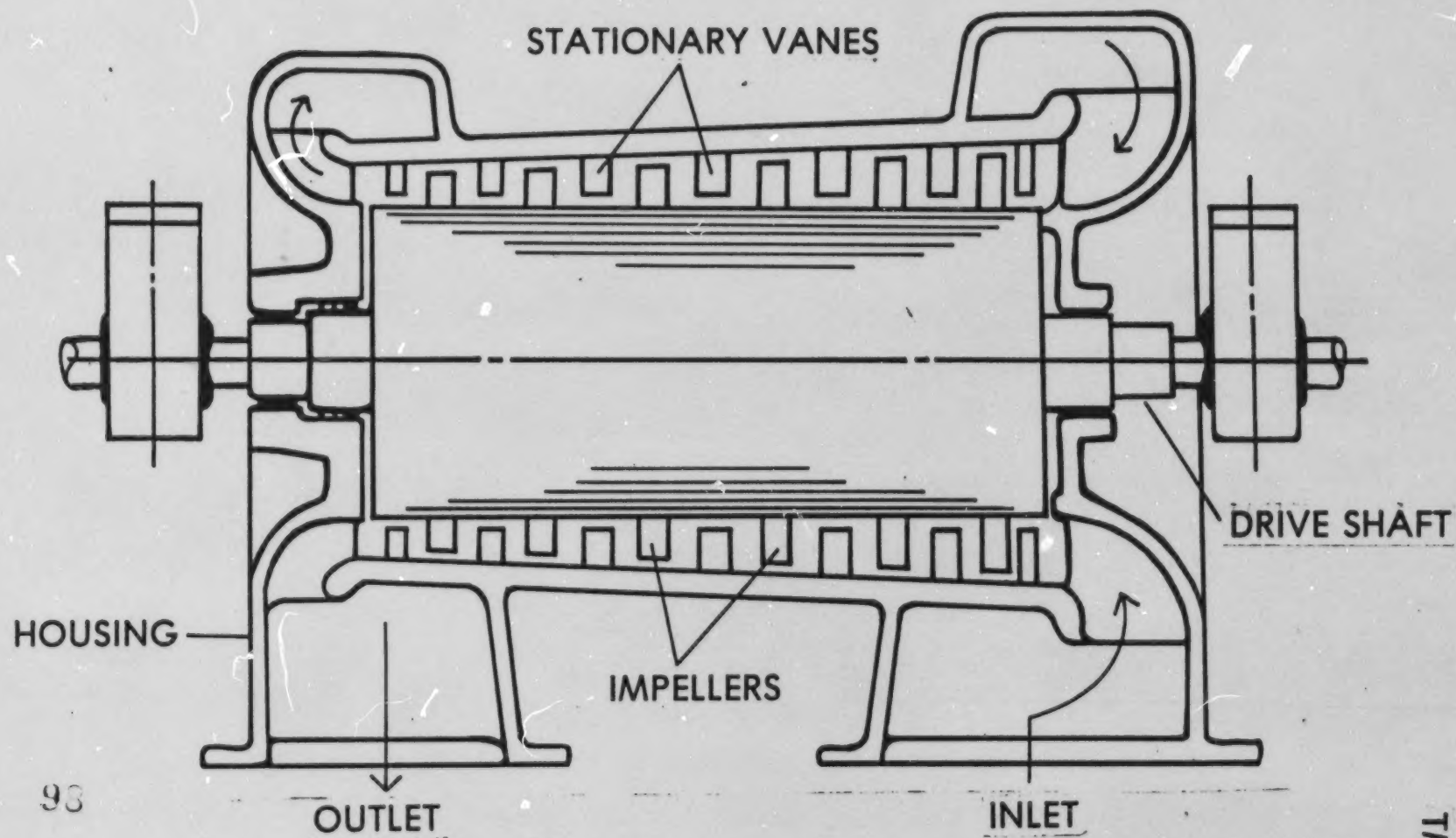
- 5.
- a. False
  - b. False
  - c. True
  - d. False
  - e. True



# RADIAL-CENTRIFUGAL COMPRESSOR



# AXIAL - CENTRIFUGAL COMPRESSOR



98

99

TM-2

LESSON PLAN: 3

COURSE TITLE: BASIC PNEUMATICS

UNIT III : AIR COMPRESSORS

SCOPE OF UNIT:

After the completion of this unit, the student should be able to name and classify the types of air compressors and identify the basic components of each type. The student should be able to outline and discuss the operating principles of each type of compressor and state the methods of compressing or increasing the pressure or the potential energy of compressed air. The student should be able to state factors that influence the installation and safe operation of compressors. The student should be able to disassemble, clean, and reassemble a simple bicycle hand pump. The student should be able to name and explain the physical laws which apply to a compressor. This knowledge will be evidenced by correctly performing the procedures outlined in the demonstration lesson and by scoring 85 percent on the evaluation items.

DEMONSTRATION: III-3

SERVICE AND OPERATION OF A BICYCLE HAND PUMP  
(Lesson Title)

LESSON OBJECTIVES - THE STUDENT SHOULD BE ABLE TO:

1. Disassemble a bicycle hand pump.
2. Clean parts of a bicycle hand pump.
3. Inspect and identify components of a bicycle hand pump.
4. Reassemble and operate a bicycle hand pump.

SUPPLEMENTARY TEACHING/LEARNING ITEMS:

1. TM 1: Operating Principles and Components of Bicycle Hand Pump
2. Adequate number of bicycle hand pumps

**INFORMATIONAL ASSIGNMENT: (Student)**

Stewart, L. Harry. Pneumatics and Hydraulics. 3rd ed. Indianapolis, IN: Theodore Audel and Co., 1978.

Industrial Pneumatic Technology, Bulletin 0275-B1. Parker Hannifin Corporation, 1980.

**REFERENCES: (Instructor's Additional Information)**

Pease, A. Dudley. Basic Fluid Power. Englewood Cliffs, NJ: Prentice-Hall Inc., 1967.

**INTRODUCTION:**

Learning to service and operate a bicycle hand pump introduces students to the operating principles of reciprocating piston compressors.



LESSON PLAN: 3

COURSE TITLE: BASIC PNEUMATICS

UNIT III : AIR COMPRESSORS

DEMONSTRATION: III-3

**TOOLS, EQUIPMENT, AND MATERIALS:**

Bicycle hand pump  
Cleaning solvent  
Lubricating oil

**STEPS OF PROCEDURE: (Job Sheet)**

**I. Disassemble**

- A. Use the cleaning solvent to clean external surface.
- B. Unscrew cylinder head end.
- C. Pull piston rod and piston unit off cylinder.

**II. Clean and inspect**

- A. Use cleaning solvent to clean all removable parts of piston and cylinder wall surface.
- B. Inspect piston for damage.
- C. Inspect flexible leather cup for nicks and cuts.
- D. Replace flexible leather cup if damaged.

**III. Reassemble**

- A. Soak flexible leather cup in oil or lubricant.
- B. Place piston rod and piston unit in cylinder.
- C. Screw or place cylinder head back in position.

**IV. Operate**

- A. Air intake stroke
  - 1. Slowly pull piston rod handle. Note that a vacuum (less than atmospheric pressure) is created in the cylinder.

2. Feel the air entering the cylinder through the inlet port or the space between the piston rod and the cylinder head end.
4. Note the position of the flexible leather cup that allows atmospheric air to enter the cylinder.

(NOTE: During air intake stroke, no air enters through check valve.)

B. Air compression stroke

1. Slowly push piston rod handle down.
2. Note how the flexible leather cup is pushed against the wall of cylinder to act as a check valve or to trap air in cylinder. Initially no air leaves cylinder through air hose.
3. Continue pushing piston rod handle down until it reaches piston cap end.
4. Feel compressed (high pressure) air leaving cylinder through air hose.

(NOTE: Check valve opens when air pressure in cylinder is greater than the outside pressure.)

LESSON PLAN: 3

COURSE TITLE: BASIC PNEUMATICS

UNIT III : AIR COMPRESSORS

DEMONSTRATION: III-3

INTERACTION ITEMS: (Review Items)

1. During the intake stroke, air enters the cylinder through the space between the flexible leather cup and the cylinder. Why?
2. During the intake stroke, air does not enter the cylinder through the check valve in the air hose. Why not?
3. During the initial few seconds of the compression stroke, air does not leave the cylinder. Why not?
4. In most common bicycle hand pumps, the check valve in the air hose does not exist, yet you are able to inflate a bicycle tire. How is this possible?
5. In this demonstration, it is possible that some of the physical laws discussed in Unit II have been in application. Name these laws and discuss how they are applied.

LESSON PLAN: 3

COURSE TITLE: BASIC PNEUMATICS

UNIT III : AIR COMPRESSORS

DEMONSTRATION: III-3

EVALUATION ITEMS:

The student has satisfactorily completed the following steps of procedure:

- I. Disassemble
- II. Clean and inspect
- III. Reassemble
- IV. Operate

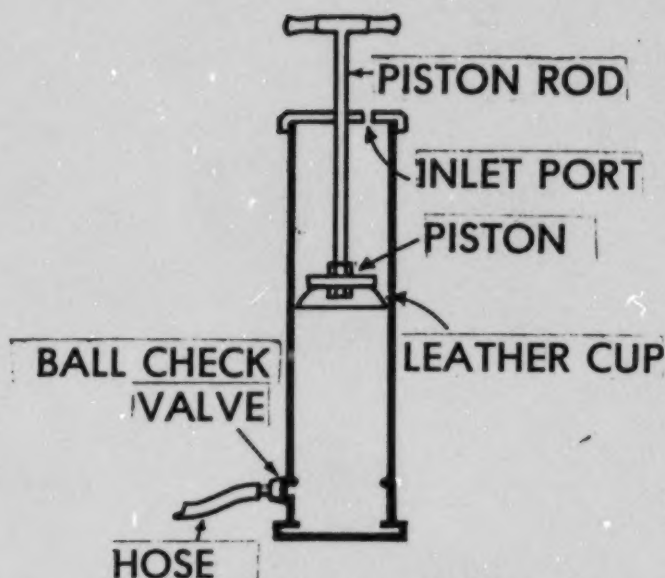
Yes \_\_\_\_ No \_\_\_\_

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Instructor's Signature  
(Verifying Satisfactory Completion)

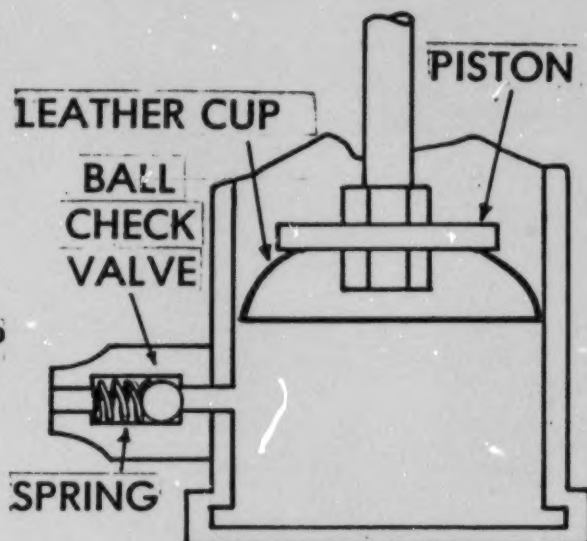
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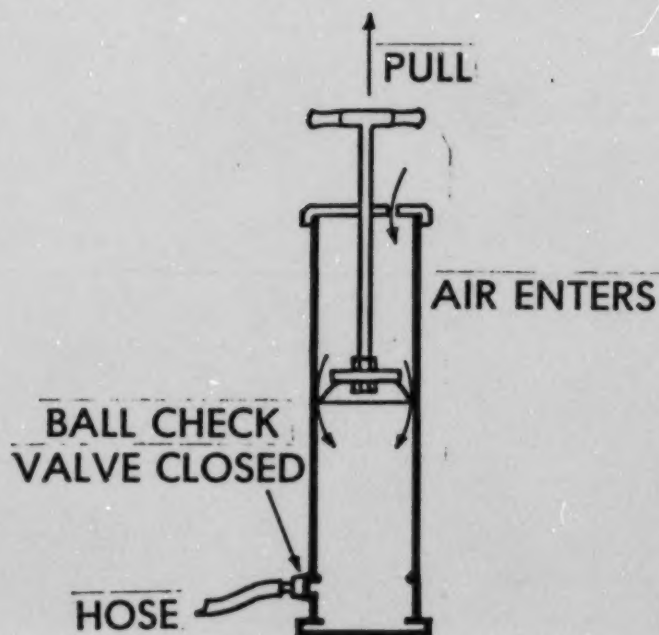
# Operating Principles of Bicycle Hand Pump



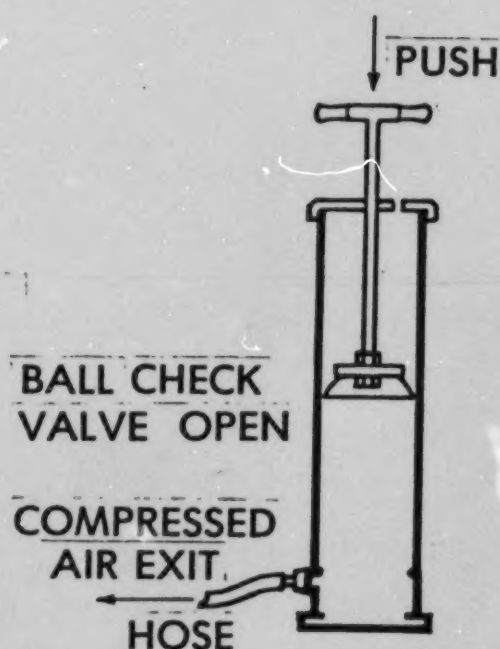
**(A) Pump Components**



**(B) Pump Details**



**(C) Intake Stroke**



**(D) Compression Stroke**

LESSON PLAN: 4

COURSE TITLE: BASIC PNEUMATICS

UNIT III : AIR COMPRESSORS

SCOPE OF UNIT:

After the completion of this unit, the student should be able to name and classify the types of air compressors and identify the basic components of each type. The student should be able to outline and discuss the operating principles of each type of compressor and state the methods of compressing or increasing the pressure or the potential energy of compressed air. The student should be able to state factors that influence the installation and safe operation of compressors. The student should be able to disassemble, clean, and reassemble a simple bicycle hand pump. The student should be able to name and explain the physical laws which apply to a compressor. This knowledge will be evidenced by correctly performing the procedures outlined in the demonstration lesson and by scoring 85 percent on the evaluation items.

INFORMATION TOPIC: III-4

COMPRESSOR INSTALLATION, SAFETY, AND NOISE CONTROL  
(Lesson Title)

LESSON OBJECTIVES - THE STUDENT SHOULD BE ABLE TO:

1. List factors which influence compressor selection.
2. State measures to be taken in locating and housing a compressor.
3. State structural requirements in mounting a compressor.
4. List measures to be taken for safe loading and unloading of a compressor.
5. State factors affecting compressor sound level.
6. List corrective measures to reduce compressor noise.

SUPPLEMENTARY TEACHING/LEARNING ITEMS:

**INFORMATIONAL ASSIGNMENT: (Student)**

Stewart, L. Harry. Pneumatics and Hydraulics. 3rd ed. Indianapolis, IN: Theodore Audel and Co., 1978.

Industrial Pneumatic Technology, Bulletin 0275-B1. Parker Hannifin Corporation, 1980.

**REFERENCES: (Instructor's Additional Information)**

Pease, A. Dudley. Basic Fluid Power. Englewood Cliffs, NJ: Prentice-Hall Inc., 1967.

**INTRODUCTION:**

Long service life and the safe and efficient operation of equipment are some of the primary criteria that should be addressed before the acquisition and utilization of a compressor.

LESSON PLAN: 4

COURSE TITLE: BASIC PNEUMATICS

UNIT III : AIR COMPRESSORS

INFORMATION TOPIC: III-4

OUTLINE: (Key Points)

- I. Factors influencing selection of compressors
  - A. Present and future air requirements
    1. Volume requirement
    2. Pressure requirement
  - B. Point of application
    1. Fixed compressor
    2. Movable compressor
  - C. Power source
    1. Electric motor
    2. Internal combustion engine
    3. Steam engine
    4. Steam turbine
  - D. Protection of workers and equipment
    1. Operator's safety
    2. Equipment safety
    3. Protection of compressor from vandalism
    4. Protection of compressor from adverse weather condition
  - E. Altitude of point of application
    1. Power requirement increases as altitude increases.
    2. Compressor output capacity decreases as altitude increases.



F. Costs

1. Initial cost
2. Operating and maintenance cost

II. Planning compressor location and housing

A. Location

1. Easily accessible
2. Close to operating and maintenance personnel
3. Close to point of application

B. Housing or compressor room

1. Adequate size
2. Clean
3. Well-lighted
4. Well-ventilated
5. Adequately insulated for both temperature/sound

III. Structural requirements for mounting a compressor

- A. Solid foundation to reduce vibration
- B. Foundation placed below the frost line
- C. Compressor mounted above floor level

IV. Measures for safe loading and unloading of a compressor

A. Satisfactory compressor loading or air input requires

1. Adequate motor
2. Properly designed air intake
3. Adequate intake pipe
4. Adequate receiver tank

B. Unloading and output control methods

1. Bypass - bleeds air to atmosphere as directed by maximum pressure setting

2. Start and stop - starting and stopping as directed by minimum and maximum pressure setting

V. Compressor noise

A. OSHA permissible noise exposure standards

| <u>(Hours)</u> | <u>(dBA)</u> |
|----------------|--------------|
| 8              | 90           |
| 6              | 92           |
| 4              | 95           |
| 3              | 94           |
| 2              | 100          |
| 1.5            | 102          |
| 1.0            | 105          |
| 0.5            | 110          |
| 0.25           | 115          |

(dBA - decibel - sound level or intensity measurement unit)

B. Factors affecting compressor sound level

1. Position of compressor relative to compressor room walls
2. Actual sound characteristics of compressor room
3. Actual sound characteristics of other equipment in compressor room
4. Foundation and mounting style
5. Air intake design
6. Air intake location
7. Air inlet pipe length
8. Air outlet (discharge) pipe length

VI. Corrective measures to reduce compressor sound level

- A. Compressor enclosure
- B. Positioning of compressor off sound-reflecting walls
- C. Positioning of compressor off sound-reflecting equipment
- D. Sound barrier or acoustic walls
- E. Short inlet pipe
- F. Short outlet (discharge) pipe
- G. Solid foundation

LESSON PLAN: 4

COURSE TITLE: BASIC PNEUMATICS

UNIT III : AIR COMPRESSORS

INFORMATION TOPIC: III-4

INTERACTION ITEMS:

1. Discuss why the compressor power requirement increases as altitude increases and compressor output capacity decreases as altitude decreases.
2. Why should the foundation of a compressor be placed below the frost line?

CLASSROOM, LABORATORY, SHOP, OR OTHER ACTIVITIES:

LESSON PLAN: 4

COURSE TITLE: BASIC PNEUMATICS

UNIT III : FUNDAMENTALS AND PHYSICAL LAWS

INFORMATION TOPIC: III-4

EVALUATION ITEMS:

1. List the factors which influence compressor selection.
2. State the measures to be considered when planning compressor location and housing.
3. State the structural requirements for mounting a compressor.
4. State the measures to be taken for safe loading and unloading of a compressor.
- 5.1. What is the permissible noise exposure level for an eight-hour work day?
- 5.2. List the factors which affect compressor sound level.
6. List the corrective measures to reduce compressor sound level.



LESSON PLAN: 4

COURSE TITLE: BASIC PNEUMATICS

UNIT III : FUNDAMENTALS AND PHYSICAL LAWS

INFORMATION TOPIC: III-4

ANSWERS TO EVALUATION ITEMS:

1. The list should include:
  - a. Present and future air requirements
    - 1) Volume requirement
    - 2) Pressure requirement
  - b. Point of application
    - 1) Fixed compressor
    - 2) Movable compressor
  - c. Power source
    - 1) Electric motor
    - 2) Internal combustion engine
    - 3) Steam engine
    - 4) Steam turbine
  - d. Protection of workers and equipment
    - 1) Operator's safety
    - 2) Equipment safety
    - 3) Protection of compressor from vandalism
    - 4) Protection of compressor from adverse weather conditions
  - e. Altitude of point of application
    - 1) Power requirement increases as altitude increases.
    - 2) Compressor output capacity decreases as altitude increases.
  - f. Costs
    - 1) Initial cost
    - 2) Operating and maintenance cost
2.
  - a. Location
    - 1) Easily accessible
    - 2) Close to operating and maintenance personnel
    - 3) Close to point of application
  - b. Housing or compressor room
    - 1) Adequate size
    - 2) Clean
    - 3) Well-lighted
    - 4) Well-ventilated
    - 5) Adequately insulated for both temperature/sound
3.
  - a. Solid foundation to reduce vibration
  - b. Foundation placed below the frost line
  - c. Compressor mounted above floor level

- 4.1.
  - a. Adequate motor
  - b. Properly designed air intake
  - c. Adequate intake pipe
  - d. Adequate receiver tank
- 4.2.
  - a. Bypass - bleeds air to atmosphere as directed by maximum pressure setting
  - b. Start and stop - starting and stopping as directed by minimum and maximum pressure setting
  - c. Inlet valve regulation - inlet valve held open when maximum pressure is reached
  - d. Inlet valve throttling - increasing or decreasing the restriction of inlet port to regulate the air which enters compressors.
- 5.1.
  - d. 90 dBA
- 5.2. The list of factors which affect compressor sound level should include:
  - a. Position of compressor relative to compressor room walls
  - b. Actual sound characteristics of compressor room
  - c. Actual sound characteristics of other equipment in compressor room
  - d. Foundation and mounting style
  - e. Air intake design
  - f. Air intake location
  - g. Air inlet pipe length
  - h. Air outlet (discharge) pipe length
- 6. List of corrective measures to reduce compressor sound level should include:
  - a. Compressor enclosure
  - b. Positioning of compressor off sound-reflecting walls
  - c. Positioning of compressor off sound-reflecting equipment
  - d. Sound barrier or acoustic walls
  - e. Short inlet pipe
  - f. Short outlet (discharge) pipe
  - g. Solid foundation

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

**SCOPE OF UNIT:**

After the completion of this unit, the student should be able to identify the different components which are installed for the preparation for compression and/or utilization of air in a pneumatic system. The student should be able to define or state the purposes and discuss the installation and operating principles of air intakes, noise control devices, air coolers, air driers, air receivers, air filters, regulators, and lubricators. The student should be able to disassemble, inspect and replace defective parts of an air filter.

**INFORMATION TOPIC: IV-1**

**AIR INTAKE, SILENCER, AND MUFFLER**  
(Lesson Title)

**LESSON OBJECTIVES - THE STUDENT SHOULD BE ABLE TO:**

1. Define and state the purposes of air intake.
2. List the measures that should be considered when designing and installing an air intake.
3. Identify the components of an air intake and state the preferred maintenance and installation practices for the components.
4. Define and state the purposes of a silencer and muffler and discuss the noise attenuation methods of a silencer and muffler.
5. Discuss the characteristics of a well-designed silencer or muffler and state the advantages of installing a silencer or muffler in a pneumatic system.
6. List the components of a muffler and discuss its operating principles.

**SUPPLEMENTARY TEACHING/LEARNING ITEMS:**

1. TM 1: Air Intake Design and Installation
2. TM 2: Pneumatic Muffler

**INFORMATIONAL ASSIGNMENT: (Student)**

Stewart, L. Harry. Pneumatics and Hydraulics. 3rd ed. Indianapolis, IN: Theodore Audel and Co., 1978.

Industrial Pneumatic Technology, Bulletin 0275-B1. Parker Hannifin Corporation, 1980.

**REFERENCES: (Instructor's Additional Information)**

Pease, A. Dudley. Basic Fluid Power. Englewood Cliffs, NJ: Prentice-Hall Inc., 1967.

**INTRODUCTION:**

In any pneumatic system, the air from the atmosphere should be processed and prepared, both before and after compression, prior to utilization. Although such preparation can be costly, it will result in minimum maintenance and wear and tear of moving parts.



LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

INFORMATION TOPIC: IV-1

OUTLINE: (Key Points)

I. Air intake

- A. Definition - a compressor air intake is a device which is equipped with an air filter and water protective measures.
- B. The purposes of an air intake are to take in:
  - 1. Clean air - to protect compressor moving parts
  - 2. Cooler air - to improve compressor efficiency

II. Air intake installation considerations (TM 1)

- A. A well-designed air intake should be installed:
  - 1. Outside the compressor room
  - 2. In a cool shady area
  - 3. 8 to 10 feet above ground
  - 4. On moisture-free surfaces
  - 5. On dust-free surfaces
  - 6. With louvers to keep off rain

III. Components of an air intake (TM 1)

- A. Air filter - to trap or strain dust particles and moisture droplets  
(NOTE: Air filter should be changed regularly because clogged filters consume power and decrease compressor efficiency.)
- B. Louvers
- C. Air intake pipe which should be
  - 1. Short if possible
  - 2. Free from scales and rust

3. Minimum pipe diameter should be 25 percent larger than the compressor piston diameter.

(NOTE: If the air pipe length is greater than 10 feet, increase the minimum diameter by one inch for every 10 feet in length.)

#### IV. Silencer or Muffler

- A. Definition - a device for reducing gas-flow follow noise
- B. Noise attenuation or reduction methods
  1. Silencer reduces gas-flow noise by tuned resonant control of gas expansion
  2. Muffler reduces gas-flow noise by back pressure control of gas expansion.

#### V. A well-designed silencer or muffler

- A. Characteristics
  1. Good sound attenuation or reduction
  2. Low resistance to flow
  3. Corrosion resistant
- B. The purposes of installing a silencer or a muffler are to:
  1. Protect operators and surroundings from exposure to harmful noise
  2. Improve operator performance
  3. Improve shop safety by allowing warning and safety signals to be heard.

#### VI. Components and operating principles of a muffler (TM 2)

- A. Components
  1. Inlet
  2. Disseminating cylinder (with perforated walls)
- B. Operating principles
  1. Air enters the muffler at high velocity.
  2. At the entrance the air mass is subdivided into many small air streams.
  3. Air streams are directed to collide with the wall and obstruction-free chamber.

4. Colliding streams rebound to collide with opposing streams to:
  - a. Reduce sound level by interposing sound waves
  - b. Reduce the velocity of the air
  - c. Increase the pressure of the air
5. Air mass leaves muffler through disseminator wall perforations.

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

INFORMATION TOPIC: IV-1

INTERACTION ITEMS:

1. Why is it preferable that the air entering a compressor be cool?
2. It is recommended that the air intake pipe should be short, if possible. If not, the minimum diameter should be increased by one inch for every 10 feet. Why?
3. Discuss why the air filter of an air intake should be replaced regularly.



LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

INFORMATION TOPIC: IV-1

EVALUATION ITEMS:

- 1.1. Define what an air intake device is.
- 1.2. List and discuss two purposes of an air intake device.
2. List six installation measures that should be considered when installing designed air intake.
  - a.
  - b.
  - c.
  - d.
  - e.
  - f.
- 3.1. List three main components of an air intake.
  - a.
  - b.
  - c.
- 3.2. State the purpose of the air filter in an air intake.
- 3.3. An air intake pipe should be:
  - a.

b.

c.

3.4. Circle the correct answer: For an air intake pipe whose length is greater than 10 feet, the minimum pipe diameter should be increased by:

- a. 1 inch
- b. 1 inch for every 10 feet
- c. 1 inch for every foot
- d. None of the above

4.1. Define a silencer or muffler.

4.2. How does a silencer reduce gas-flow noise?

4.3. How does a muffler reduce gas-flow noise?

5.1. A well-designed silencer or muffler is one with:

a.

b.

c.

5.2. What are the advantages of installing a silencer or a muffler?

6.1. List the components of a muffler.

6.2. Discuss the operating principles of a muffler.

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

INFORMATION TOPIC: IV-1

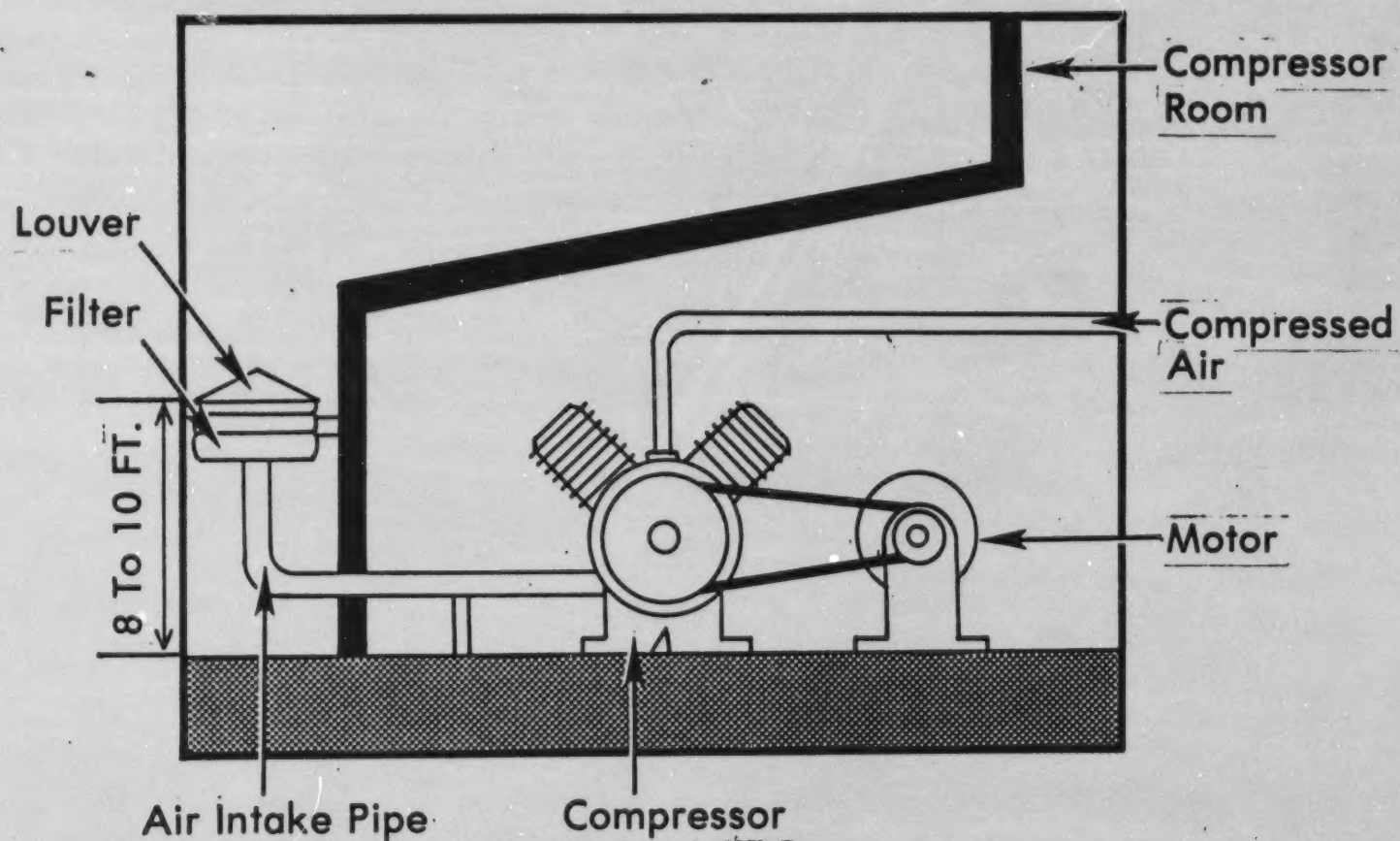
ANSWERS TO EVALUATION ITEMS:

- 1.1. A compressor air intake is a device which is equipped with air filter and water protective measures.
- 1.2. The purpose of an air intake is to take in
  - a. Clean air to protect compressor moving parts
  - b. Cooler air to improve compressor efficiency
- 2.1. A well-developed air intake should be installed
  - a. Outside the compressor room
  - b. In a cool shady area
  - c. 8 to 10 feet above ground
  - d. On moisture-free surfaces
  - e. On dust-free surfaces
  - f. With louvers to keep off rain
- 3.1.
  - a. Air filter
  - b. Air pipe
  - c. Louvers
- 3.2. The purpose of air filter in an air intake is to trap or strain dust particles and moisture droplets.
- 3.3.
  - a. Short if possible
  - b. Free from scale and rust
  - c. With minimum diameter 25 percent larger than the compressor piston diameter.
- 3.4.
  - b.
- 4.1. A device for reducing gas-flow noise
- 4.2. A silencer reduces gas-flow noise by tuned resonant control of gas expansion.
- 4.3. Muffler reduces gas-flow noise by back pressure control of gas expansion.
- 5.1.
  - a. Good sound attenuation or reduction
  - b. Low resistance to flow
  - c. Corrosion resistant
- 5.2. The advantages of installing a silencer or muffler are to
  - a. Protect operators and surroundings from exposure to harmful noise
  - b. Improve operator performance

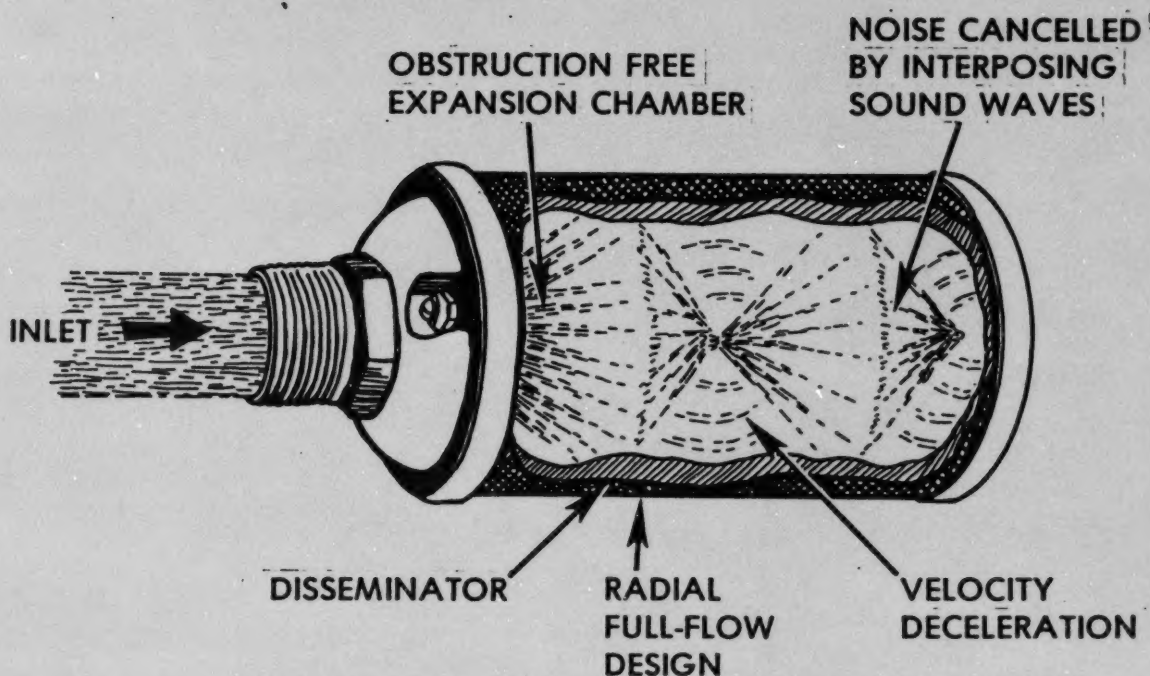
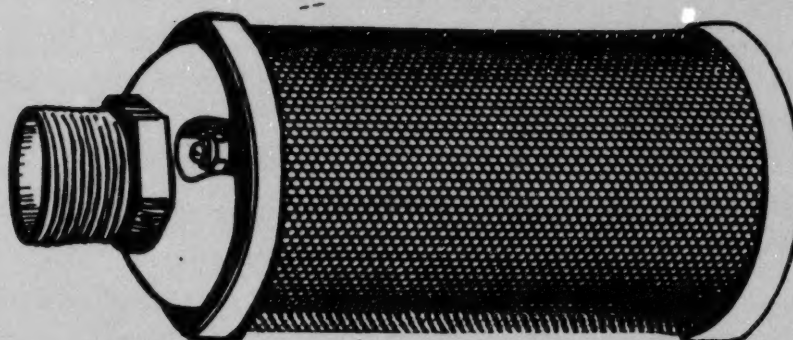
- c. Improve shop safety by allowing warning and safety signals to be heard.
- 6.1.
  - a. Inlet
  - b. Disseminating cylinder
- 6.2. Discussion of the operating principles of a muffler should include:
  - a. Air enters the muffler at high velocity.
  - b. At entrance air mass is subdivided into many small air streams.
  - c. Air streams are directed to collide with the wall and obstruction-free chamber.
  - d. Colliding streams rebound to collide with opposing streams to:
    - i. Reduce sound level by interposing sound waves
    - ii. Reduce the velocity of the air
    - iii. Increase the pressure of the air
  - e. Air mass leaves muffler through disseminator wall perforations



# AIR INTAKE DESIGN AND INSTALLATION



# PNEUMATIC MUFFLER



LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

SCOPE OF UNIT:

After the completion of this unit, the student should be able to identify the different components which are installed for the preparation for compression and/or utilization of air in a pneumatic system. The student should be able to define or state the purposes and discuss the installation and operating principles of air intakes, noise control devices, air coolers, air driers, air receivers, air filters, regulators, and lubricators. The student should be able to disassemble, inspect and replace defective parts of an air filter.

INFORMATION TOPIC: IV-2

AIR COOLERS AND AIR DRIERS  
(Lesson Title)

LESSON OBJECTIVES - THE STUDENT SHOULD BE ABLE TO:

1. Define air coolers.
2. Name and describe the types of air coolers.
3. Name and describe the types of coolant or cooling mediums.
4. List and identify the components of a typical intercooler and discuss its cooling mechanism.
5. List and identify the components of a typical aftercooler and discuss its cooling mechanism.
6. Describe air driers and state their purposes.
7. Discuss air drying by the adsorption method, list the common adsorption chemicals and state the advantages and disadvantages of drying air by adsorption.
8. Discuss air drying by the absorption method, list the common non-liquifying and liquifying absorption chemicals and state the advantages and disadvantages of air drying by absorption.
9. Discuss the air drying process which utilizes a liquifying absorption chemical.

SUPPLEMENTARY TEACHING/LEARNING ITEMS:

1. TM 1: Typical Intercooler
2. TM 2: Typical Aftercooler
3. TM 3: Air Drier (Liquifying Absorption Chemical)

**INFORMATIONAL ASSIGNMENT: (Student)**

Stewart, L. Harry. Pneumatics and Hydraulics. 3rd ed. Indianapolis, IN: Theodore Audel and Co., 1978.

Industrial Pneumatic Technology, Bulletin 0275-B1. Parker Hannifin Corporation, 1980.

**REFERENCES: (Instructor's Additional Information)**

Pease, A. Dudley. Basic Fluid Power. Englewood Cliffs, NJ: Prentice-Hall Inc., 1967.

**INTRODUCTION:**

In any pneumatic system, the air from the atmosphere should be processed and prepared, both before and after compression, prior to utilization. Although such preparation can be costly, it will result in minimum maintenance and wear and tear of moving parts.



LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

INFORMATION TOPIC: IV-2

OUTLINE: (Key Points)

- I. Air cooler - a device or heat exchanger that is used to cool or remove heat from air or a gaseous mass.

(NOTE: A heat exchanger is a device which transfers heat from one fluid to another through a heat conducting wall, i.e., refrigerators and air conditioners.)

- II. Types of air coolers

- A. Precooler - a heat exchanger which cools air before it is compressed
- B. Intercooler - a heat exchanger which cools air between the compressive steps of a multi-stage compressor
- C. Aftercooler - a heat exchanger which cools air after it is compressed

- III. Coolant or cooling mediums

- A. Air - air takes heat from the air or fluid to be cooled

(NOTE: Normally, precoolers and intercoolers are air-cooled.)

- B. Water - water takes heat from the air or fluid to be cooled.

(NOTE: Normally, aftercoolers are water-cooled. The cooling medium should be colder than the air to be cooled.)

- IV. Typical intercooler (TM 1)

- A. Components and their functions

1. Fan - to direct cool air past the conducting fins
2. Fins - metal plates which conduct heat from the hot compressed air
3. Core tube - connects two successive compression stages.

- B. Cooling mechanism

1. Hot air from the first stage compressor enters connecting core tube.
2. Heat from the compressed air is transferred to core tube and fins by conduction.

3. Fan directs cool air through the fins where the cool air absorbs heat from the core tube and fins, thus cooling the compressed air.

#### V. Typical aftercooler (TM 2)

##### A. Components

1. Cold water inlet
2. Hot air inlet
3. Warm water outlet
4. Cool air outlet
5. Water jacket
6. Core tubes

##### B. Cooling mechanism

1. Hot air from compressor enters the aftercooler.
2. Entering hot air is subdivided and flows through the core tubes where heat from the air is absorbed.
3. Cooling water enters water jacket on the downstream side of the aftercooler.
4. Cooling water absorbs heat from the core tubes as it flows to exit in the opposite directions.
5. Cooled compressed air leaves the aftercooler on the downstream side.

#### VI. Drier - a device which dries or removes moisture from compressed air.

#### VII. Adsorption

- ##### A. Definition - a method of drying moist air where the moisture is adsorbed in small pores in the drying chemical or desiccant.

##### B. Common adsorption chemicals

1. Silica gel
2. Activated alumina

##### C. Advantages and disadvantages of adsorption

1. Advantage
  - a. Adsorption chemicals need not be replaced but regenerated

2. Disadvantages

- a. High initial cost
- b. Regeneration of adsorption chemical can be costly

VIII. Absorption

A. Definition - a method of drying moist air where the moisture is absorbed by the drying chemical or desiccant and reacts chemically with the drying agent.

B. Common absorption chemicals

- 1. Nonliquifying - solids which do not liquify or dissolve when moisture is absorbed
  - a. Dehydrated chalk
  - b. Magnesium perchlorate
- 2. Liquifying - solids which liquify or dissolve when moisture is absorbed.
  - a. Calcium chloride
  - b. Lithium chloride

C. Advantages of disadvantages of absorption

1. Advantages

- a. Low initial cost
- b. Low maintenance cost

2. Disadvantages

- a. Can be corrosive
- b. Causes excessive pressure drop in air line
- c. Requires replacement of drying chemicals

IX. Steps in absorption process (liquifying drying chemical) (TM 3)

- A. Moist air enters drying chamber at the bottom.
- B. Moist air flows up through the drying chemical or desiccant.
- C. Moisture is absorbed by drying agent.
- D. Dry air leaves chamber at the top.

- E. Liquified drying agent drops to the bottom of the chamber to be subsequently drained.



LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

INFORMATION TOPIC: IV-2

INTERACTION ITEMS: (Review Items)

1. What will happen if the cooling medium is hotter than the air to be cooled?
2. Can you explain why air gets heated when it is compressed?
3. Why should you spend money to dry compressed air before it is used to do useful work?

LESSON PLAN: 2

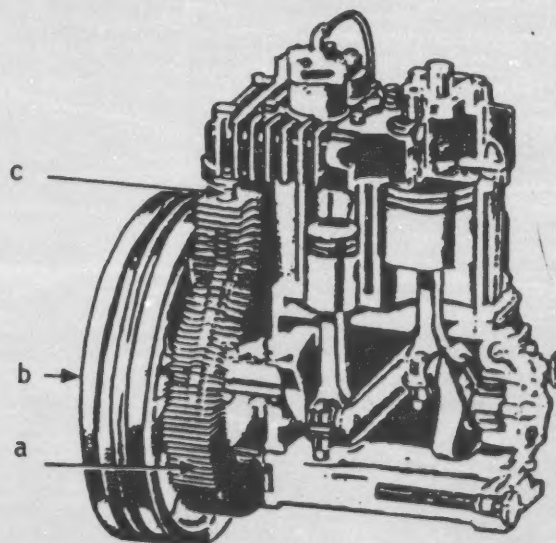
COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

INFORMATION TOPIC: IV-2

EVALUATION ITEMS:

1. Define air cooler.
2. Name and describe three types of air coolers.
  - a.
  - b.
  - c.
3. Name and describe two common types of coolant or cooling medium of an air cooler.
  - a.
  - b.
- 4.1. For the air-cooled intercooler shown in the diagram below, identify and write the names of each component next to the appropriate letter and indicate by arrows the relative motion of the fluids involved.
  - a.
  - b.
  - c.



4.2. With reference to the diagram shown above, discuss the cooling mechanism of an air-cooled intercooler.

5.1. For the water-cooled aftercooler shown in the diagram below, identify and write the names of each component in the space next to the appropriate letter and indicate by arrows the relative motion of the fluids involved.

a.

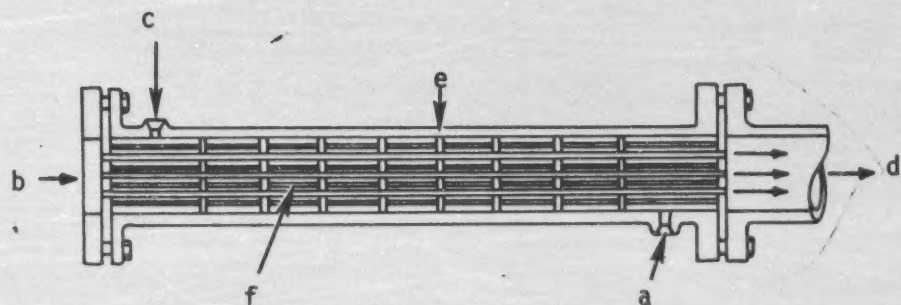
b.

c.

d.

e.

f.



5.2. With reference to the diagram shown above, discuss the cooling mechanism of a water-cooled aftercooler.

6. What is the purpose of the air drier in a pneumatic system?

7.1. Describe air drying by adsorption.

7.2. Name two common adsorption chemicals.

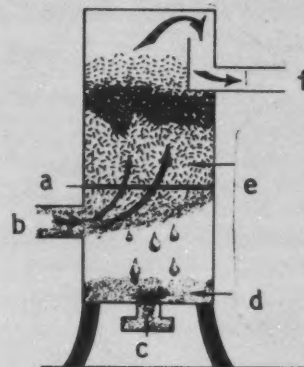
a.

b.

7.3. What are the advantages and disadvantages of drying air by adsorption.

- 8.1. Describe air drying by absorption.
- 8.2. Describe a nonliquifying absorption drying chemical.
- 8.3. Name two common nonliquifying absorption chemicals.
  - a.
  - b.
- 8.4. Describe a liquifying absorption drying chemical.
- 8.5. Name two common liquifying absorption chemicals.
  - a.
  - b.
- 8.6. What are the advantages and disadvantages of drying air by absorption?
- 9.1. For the absorption air drier shown in the diagram below, identify and write the name of each component in the space next to the appropriate letter and indicate by arrows the relative motion of the fluids involved.

- a.
- b.
- c.
- d.
- e.
- f.



- 9.2. With reference to the diagram shown above, discuss the absorption drying process if a liquifying drying chemical is used.



LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

INFORMATION TOPIC: IV-2

ANSWERS TO EVALUATION ITEMS:

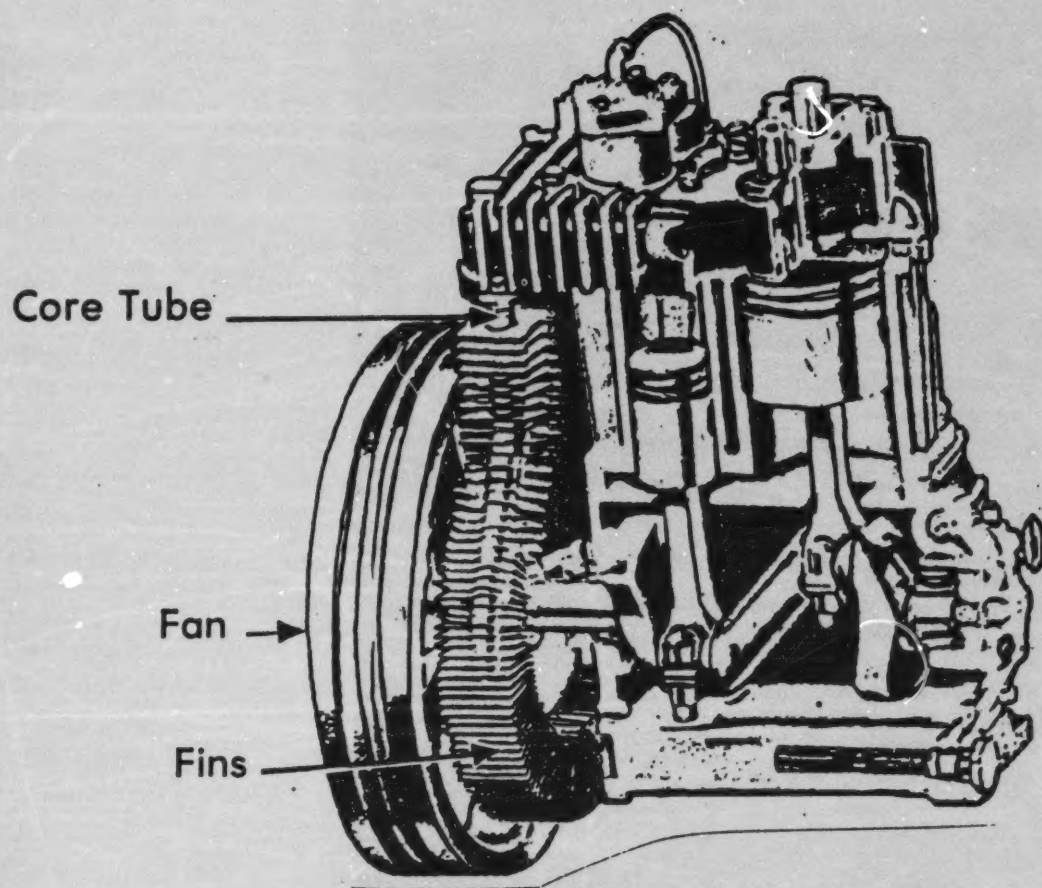
1. An air cooler is a device or heat exchanger that is used to cool or remove heat from air or gaseous mass.
2.
  - a. Precooler is a heat exchanger which cools air before it is compressed.
  - b. Intercooler is a heat exchanger which cools air between the compressive steps of a multi-stage compressor
  - c. Aftercooler is a heat exchanger which cools air after it is compressed.
3.
  - a. Air-cooled uses air as the medium to take heat from the air or fluid to be cooled.
  - b. Water-cooled uses water as the medium to take heat from the air or fluid to be cooled.
- 4.1.
  - a. Fins
  - b. Fan
  - c. Core tube
- 4.2. Discussion should include:
  - a. Hot air from the first stage compressor enters connecting core tube.
  - b. Heat from the compressed air is transferred to core tube and fins by conduction.
  - c. Fan directs cool air through the fins where the cool air absorbs heat from the core tube and fins, thus cooling the compressed air.
- 5.1.
  - a. Cold water inlet
  - b. Hot air inlet
  - c. Warm water outlet
  - d. Cool air outlet
  - e. Water jacket
  - f. Core tubes
- 5.2. Discussion should include:
  - a. Hot air from compressor enters the aftercooler.
  - b. Entering hot air is subdivided and flows through the core tubes where heat from the air is absorbed.
  - c. Cooling water enters water jacket on the downstream side of the aftercooler.

- d. Cooling water absorbs heat from the core tubes as it flows to exit in the opposite directions.
  - e. Cooled compressed air leaves the aftercooler on the downstream side.
6. A drier is a device which dries or removes moisture from compressed air.
- 7.1. Adsorption is a method of drying moist air where the moisture is adsorbed in small pores in the drying chemical or desiccant.
- 7.2. a. Silica gel  
b. Activated alumina
- 7.3. a. Advantage  
1. Absorption chemical need not be replaced but regenerated  
b. Disadvantages  
1. High initial cost  
2. Regeneration of adsorption chemical can be costly
- 8.1. Absorption is a method of drying moist air where the moisture is absorbed by the drying chemical or desiccant.
- 8.2. Nonliquifying - solids which do not liquify or dissolve when moisture is absorbed.
- 8.3. a. Dehydrated chalk  
b. Magnesium perchlorate
- 8.4. Liquifying absorption drying chemicals are solids which liquify or dissolve when moisture is absorbed.
- 8.5. a. Calcium chloride  
b. Lithium chloride
- 8.6. a. Advantages  
1. Low initial cost  
2. Low maintenance cost  
b. Disadvantages  
1. Can be corrosive  
2. Causes excessive pressure drop in air line  
3. Requires replacement of drying chemicals
- 9.1. a. Moist air inlet  
b. Dry air outlet  
c. Dry chemical  
d. Salt solution  
e. Screen  
f. Drain

9.2. The discussion should include:

- a. Moist air enters drying chamber at the bottom.
- b. Moist air flows up through the drying chemical or desiccant.
- c. Moist air is absorbed by drying agent.
- d. Dry air leaves chamber at the top.
- e. Liquified drying agent drops to the bottom of the chamber to be subsequently drained.

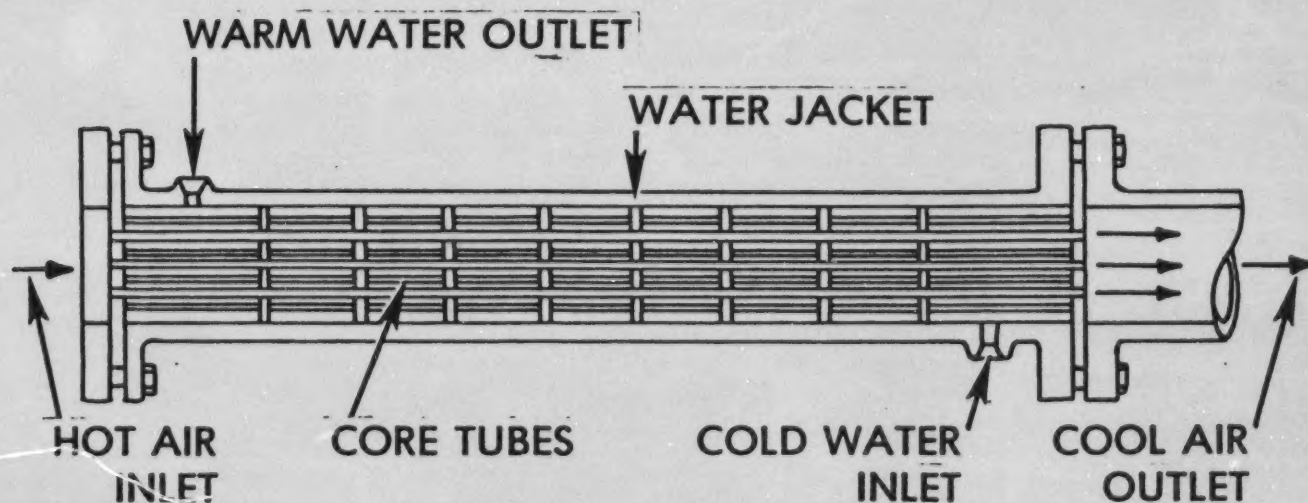
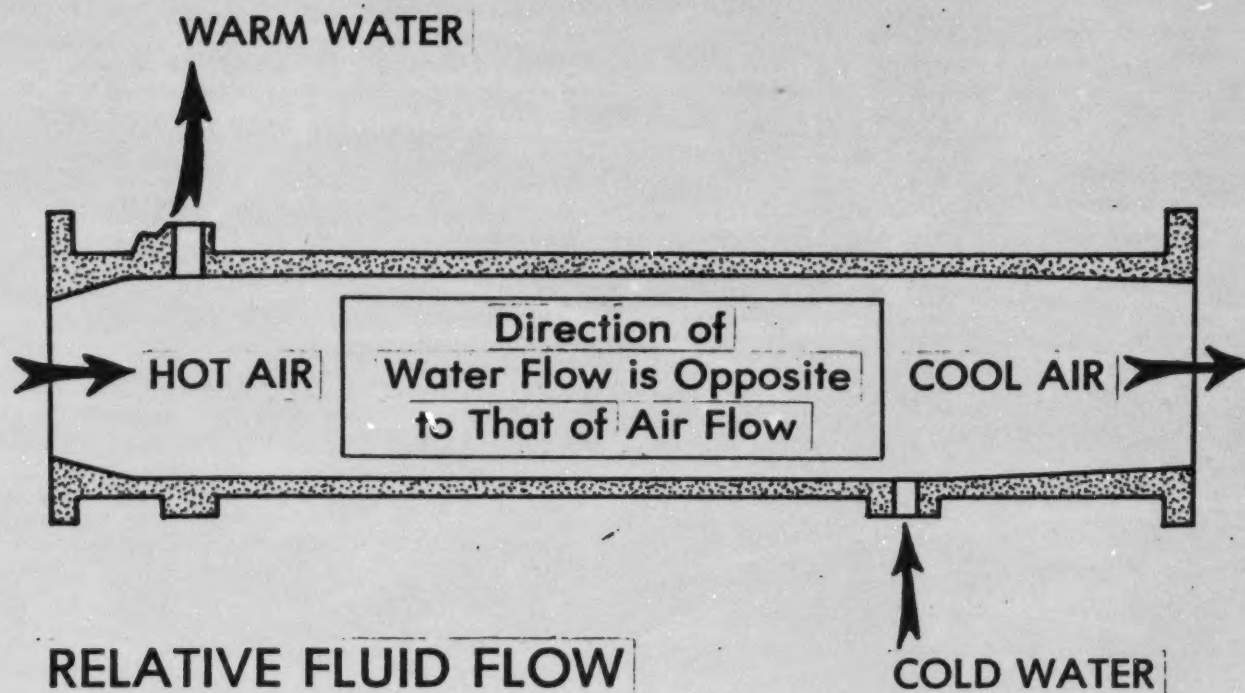
# Typical Intercooler





# TYPICAL AFTERCOOLER

TM-2

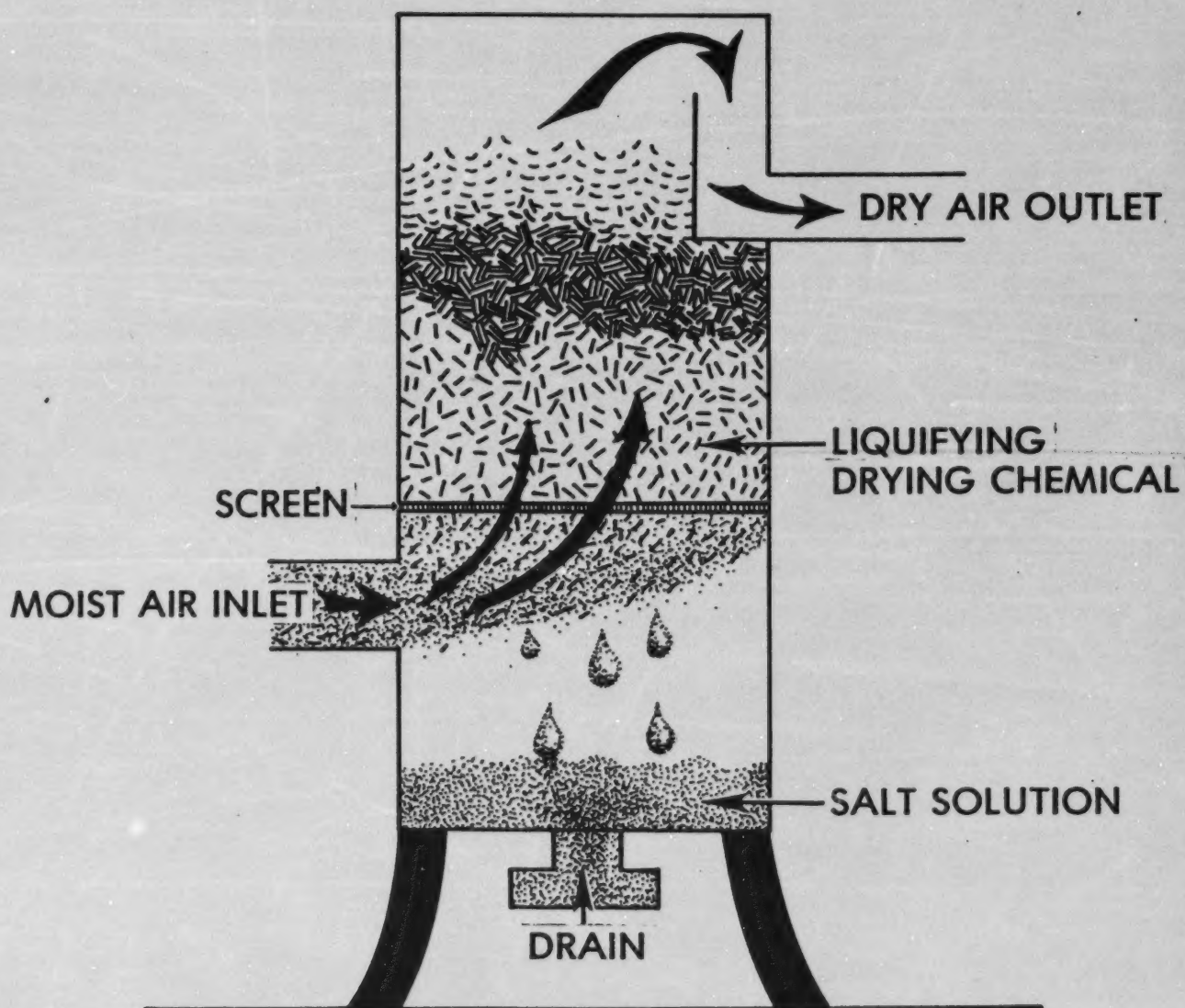


## COMPONENTS OF AN AFTERCOOLER

# AIR DRIER

(LIQUIFYING ABSORPTION CHEMICAL)

TM-3



LESSON PLAN: 3

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

SCOPE OF UNIT:

After the completion of this unit, the student should be able to identify the different components which are installed for the preparation for compression and/or utilization of air in a pneumatic system. The student should be able to define or state the purposes and discuss the installation and operating principles of air intakes, noise control devices, air coolers, air driers, air receivers, air filters, regulators, and lubricators. The student should be able to disassemble, inspect and replace defective parts of an air filter.

INFORMATION TOPIC: IV-3

RECEIVER TANK  
(Lesson Title)

LESSON OBJECTIVES - THE STUDENT SHOULD BE ABLE TO:

1. Define and state the purposes of an air receiver tank.
2. Discuss receiver tank installation and mounting.
3. State the factors which influence receiver tank sizing.
4. Determine the size (volume) of a receiver tank under constant and/or variable working pressure demand.

SUPPLEMENTARY TEACHING/LEARNING ITEMS:

1. TM 1: Receiver Tank

**INFORMATIONAL ASSIGNMENT: (Student)**

Stewart, L. Harry. Pneumatics and Hydraulics. 3rd ed. Indianapolis, IN: Theodore Audel and Co., 1978.

Industrial Pneumatic Technology, Bulletin 0275-B1. Parker Hannifin Corporation, 1980.

**REFERENCES: (Instructor's Additional Information)**

Pease, A. Dudley. Basic Fluid Power. Englewood Cliffs, NJ: Prentice-Hall Inc., 1967.

**INTRODUCTION:**

One of the advantages of pneumatics over hydraulic systems is that air under high pressure can be stored in compact receiver tanks, making pneumatics less costly and more mobile.



LESSON PLAN: 3

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

INFORMATION TOPIC: IV-3

OUTLINE: (Key Points)

I. Air receiver tank

- A. Definition - a sealed tank where an air mass from a compressor is stored under high pressure for future use.
- B. Purpose
  - 1. Stores pressurized air for future use.
  - 2. Assures a steady supply of pressurized air.
  - 3. Reduces or dampens the pulsation created by intermittent flow of air from a compressor.
  - 4. Minimizes the frequency of loading (on) and unloading (off) of compressor motor.
  - 5. Serves as a place for contaminants and dust particle fallout.

II. Receiver tank installation and mounting (TM 1)

- A. Place near the compressor.
- B. Make provisions to see that it is of adequate size (capacity).
- C. Provide baffles to slow air velocity in the tank.
- D. Be sure that it meets local and state safety code requirements.
- E. Provide safety valve to release excess pressure.
- F. Provide pressure gage.
- G. Provide stop valve on the downstream (discharge) side.
- H. Provide check valve between receiver tank and compressor.
- I. Provide moisture drain at the lowest point of the tank. (For a horizontal cylindrical receiver tank, it is a good practice to tilt the tank to insure good drainage.)

### III. Factors influencing receiver tank size

- A. Compressor output
- B. Air demand (volume and pressure)
- C. Duration of air demand
- D. Compressor loading and unloading frequency

### IV. Receiver tank volume determination

- A. For constant pressure demand, the volume of a receiver tank is estimated by

$$V = \frac{KQ \times P_a}{P_1 + P_a}$$

Where

V = Volume of receiver tank in cubic feet (cf)

Q = Compressor output in cubic feet per minute (cfm)

P<sub>a</sub> = Standard atmospheric pressure in psig, normally taken as 14.7 psig.

P<sub>1</sub> = Compressed air pressure (psia)

K = A constant factor normally equal to 3.

Example: A compressor has an output of 500 cfm. If the working pressure demanded is 100 psia, what size receiver tank is needed?

Receiver tank volume,  $V = \frac{KQ \times P_a}{P_1 + P_a}$

$$V = \frac{3 \times 500 \times 14.7}{100 + 14.7} = 191.3 \text{ cf}$$

- B. For variable pressure demand, the volume of a receiver tank is estimated by

$$V = \frac{t(Q_{out} - Q_{in}) \times P_a}{P_1 - P_2}$$

Where

V = Volume of receiver tank in cubic feet (cf)

t = Time to charge (fill) or to discharge (drain) the receiver tank, in minutes

Q<sub>out</sub> = Air flow rate out of receiver tank in cfm

Q<sub>in</sub> = Air flow rate into receiver tank in cfm

P<sub>a</sub> = Standard atmospheric pressure in psig, normally taken as 14.7 psig.

P<sub>1</sub> = Initial working pressure (psia)

P<sub>2</sub> = Final working pressure (psia)

Example: a compressor has an output of 300 cfm and the pneumatic system requires 400 cfm for 1 minute. If the initial working pressure demanded is 100 psia and the pressure can drop to 80 psia, what size receiver tank is needed?

$$\text{Receiver tank volume, } V = \frac{t(Q_{\text{out}} - Q_{\text{in}}) \times P_a}{P_1 - P_2}$$

$$V = \frac{1.0 (400 - 300) \times 14.7}{100 - 80}$$

$$V = \frac{1.0 \times 100 \times 14.7}{20} = 73.5 \text{ cf}$$

LESSON PLAN: 3

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

INFORMATION TOPIC: IV-3

INTERACTION ITEMS: (Review Items)

1. Why is it necessary to install a check valve between the compressor and the receiver tank?
2. Why is it necessary to install a stop valve on the discharge side of an air receiver?
3. In addition to reducing air flow velocity inside a receiver tank, is there any other advantage(s) of installing baffles inside a receiver tank?
4. Why should horizontal cylindrical receiver tanks be tilted towards one side?

CLASSROOM, LABORATORY, SHOP, OR OTHER ACTIVITIES:



LESSON PLAN: 3

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

INFORMATION TOPIC: IV-3

EVALUATION ITEMS:

- 1.1. Define a receiver tank.
- 1.2. What are the purposes of the receiver tank in a pneumatic systems?
- 2.1. List at least six measures which should be taken when installing and mounting a receiver tank.
  - a.
  - b.
  - c.
  - d.
  - e.
  - f.
- 3.1. List the factors which influence the size of a receiver tank.
- 4.1. A compressor has an output of 400 cfm. If a constant working pressure of 120 psia is demanded, what size receiver tank is needed? (Use  $K = 3$ .)
- 4.2. A compressor has an output of 400 cfm and the pneumatic system requires 500 cfm for half a minute. If the initial working pressure demanded is 120 psia and the pressure can drop to 100 psia, what size receiver tank is needed?

LESSON PLAN: 3

COURSE TITLE: BASIC PNEUMATICS

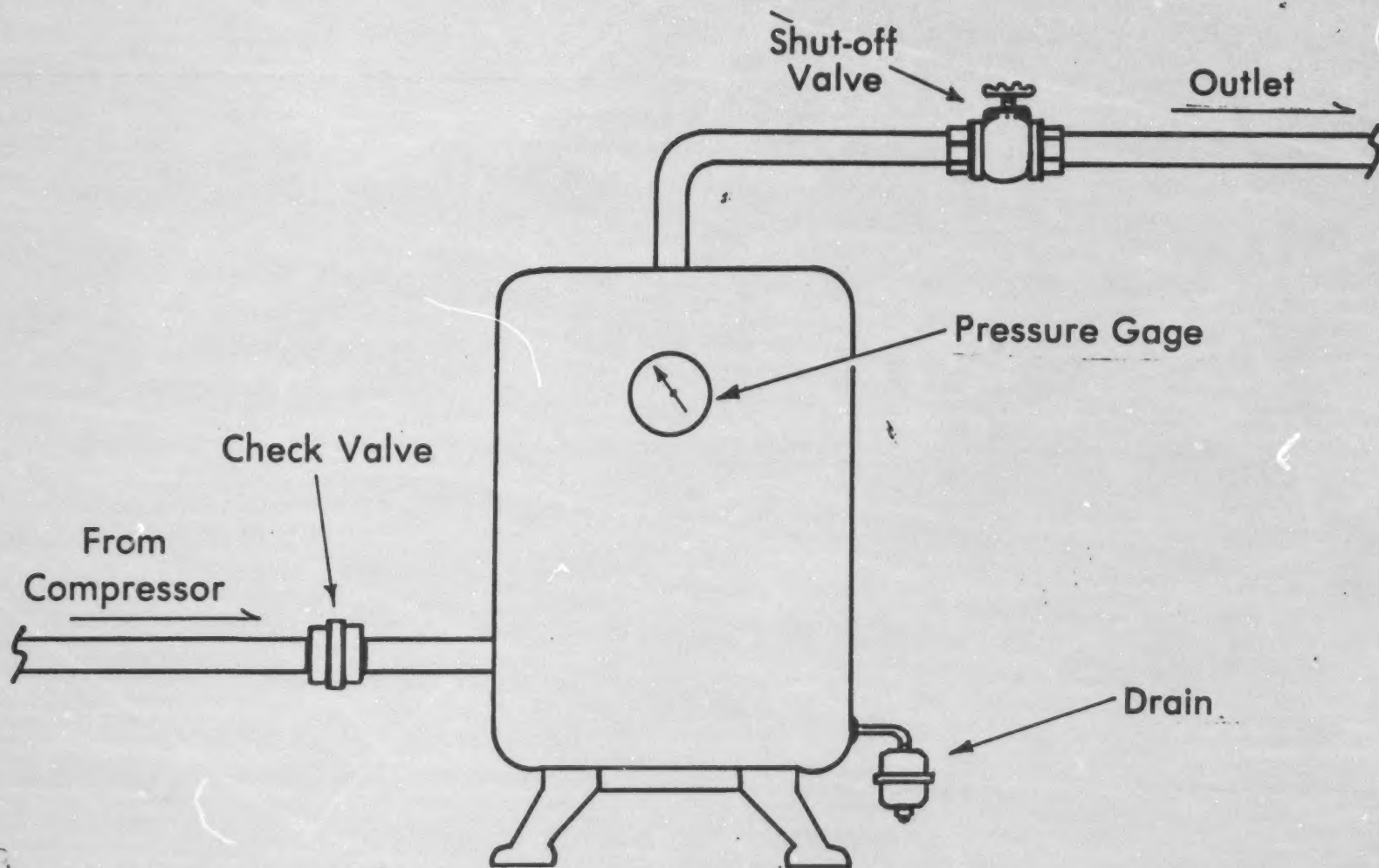
UNIT IV : COMPRESSOR ACCESSORIES

INFORMATION TOPIC: IV-3

ANSWERS TO EVALUATION ITEMS:

- 1.1 A receiver tank is a sealed tank where an air mass from a compressor is stored under high pressure for future use.
- 1.2. a. Stores pressurized air for future use.  
b. Assures a steady supply of pressurized air.  
c. Reduces or dampens the pulsation created by intermittent flow of air from a compressor.  
d. Minimizes the frequency of loading (on) and unloading (off) of compressor motor.  
e. Serves as a place for contaminants and dust particle fallout.
- 2.1. Receiver tank installation and mounting measures  
a. Place near the compressor.  
b. Make provisions for adequate size.  
c. Provide baffles to slow air velocity in the tank.  
d. Be sure that it meets local and state safety code requirements.  
e. Provide safety valve to release excess pressure.  
f. Provide pressure gage.  
g. Provide stop valve on the downstream (discharge) side.  
h. Provide check valve between receiver tank and compressor.  
i. Provide moisture drain at the lowest point of the tank.
- 2.1. Receiver tank installation <sup>and</sup> ~~of~~ mounting measures  
a. Compressor output  
b. Air demand (volume and pressure)  
c. Duration of air demand  
d. Compressor loading and unloading frequency.
- 4.1. 130.9 cf
- 4.2. 36.75 cf

# Receiver Tank



LESSON PLAN: 4

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

SCOPE OF UNIT:

After the completion of this unit, the student should be able to identify the different components which are installed for the preparation for compression and/or utilization of air in a pneumatic system. The student should be able to define or state the purposes and discuss the installation and operating principles of air intakes, noise control devices, air coolers, air driers, air receivers, air filters, regulators, and lubricators. The student should be able to disassemble, inspect and replace defective parts of an air filter.

INFORMATION TOPIC: IV-4

AIR FILTER-REGULATOR-LUBRICATOR  
(Lesson Title)

LESSON OBJECTIVES - THE STUDENT SHOULD BE ABLE TO:

1. List the considerations for the design and installation of an air filter-regulator-lubricator unit.
2. State the purpose of an air filter in a pneumatic system.
3. List the types of air filters.
4. Identify the components of a typical screen-type air filter and discuss its operating principles and maintenance.
5. Describe and state the purposes of a regulator.
6. List and describe the types of regulator.
7. Identify the components of a typical venting spring-controlled piston-type regulator and discuss its operating principles.
8. Identify the components of a typical nonventing pilot-controlled piston-type regulator and discuss its operating principles.
9. Describe or state the purpose of a lubricator in a pneumatic system.
10. Identify the components of a typical lubricator and discuss its operating principles at high air flow.
11. State the difference in operating principles of a lubricator under high and low air flows.

SUPPLEMENTARY TEACHING/LEARNING ITEMS:

1. TM 1: Air Filter (Screen-Type)
2. TM 2: Regulator (Venting Type)
3. TM 3: Regulator (Nonventing Type)
4. TM 4: Components of a Typical Lubricator
5. TM 5: Typical Lubricators



**INFORMATIONAL ASSIGNMENT: (Student)**

Stewart, L. Harry. Pneumatics and Hydraulics. 3rd ed. Indianapolis, IN: Theodore Audel and Co., 1978.

Industrial Pneumatic Technology, Bulletin 0275-B1. Parker Hannifin Corporation, 1980.

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**INTRODUCTION:**

One of the advantages of pneumatics over hydraulic systems is that air under high pressure can be stored in compact receiver tanks, making pneumatics less costly and more mobile.

LESSON PLAN: \_\_\_\_\_

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

INFORMATION TOPIC: IV-4

OUTLINE: (Key Points)

I. Air filter-regulator-lubricator unit design and installation considerations

- A. Sized for maximum flow rate
- B. Mounted near the point of application
- C. Easily accessible for maintenance and operation
- D. Provided with shut off valve upstream of the unit
- E. Placed at a higher elevation than the point of application

II. Air filter

- A. Definition - a device which filters or removes contaminant particles from compressed air in the receiver tank or compressor
- B. Air contaminant particles in a pneumatic system include:
  - 1. Dust particles
  - 2. Pipe scale and rust
  - 3. Emulsified compressor oil droplets
  - 4. Condensed water vapor

III. Types of air filters

- A. Screen
- B. Mechanical

IV. Typical screen-type air filter (TM 1)

- A. Components
  - 1. Inlet port
  - 2. Deflector
  - 3. Shrouder

4. Filter element or screen
5. Filter bowl
6. Baffle
7. Drain cock
8. Outlet port

B. Operation of an air filter

1. Air from the receiver tank or compressor enters the inlet port.
2. Deflector deflects the air causing it to swirl in a circular motion.
3. Heavy particles and liquid drops are thrown out to the interior wall of the bowl by centrifugal force.
4. Heavy particles and liquid drops run down the sides of the bowl to the bottom of the bowl.
5. Shrouder distributes the air mass at a uniform rate across the filter element.
6. The filter element removes smaller particles before the air mass exits through the outlet port.

C. Maintenance of air filter

1. Periodic draining of filtered particles, is required if filter drain is not automatic
2. Periodic replacement of filter element helps to avoid excessive head (pressure) loss of time.

V. Regulator

A. Definition - a device which provides or maintains a constant supply of pressure to the work point of a pneumatic system.

B. Purposes of regulator

1. Maintains constant pressure regardless of the pressure fluctuation in the air line
2. Saves compressed air by regulating the flow
3. Reduces pressure to a level which meets work requirement.
4. Produces controlled pressure in systems where variable air pressure is needed.

VI. Types of regulator

A. Venting - regulator which releases excess air from the downstream side to equalize an excess pressure to a designated (set) working pressure requirement

1. Piston-type
2. Diaphragm-type

B. Nonventing - regulator which equalizes an excess pressure to a designated working pressure by restricting flow of air from the upstream side

1. Piston-type
2. Diaphragm-type

(NOTE: A nonventing regulator can be spring-controlled or pilot-controlled.)

#### VII. Typical venting spring-controlled piston-type regulator (TM 2)

A. Components

1. Inlet port
2. Outlet port
3. Vent holes
4. Pressure adjusting screw
5. Spring
6. Piston
7. Pilot passage
8. Air passage
9. Poppet
10. Body

B. Operating principles

1. As the pressure on the downstream rises or drops it is sensed on the underside of the piston.
2. When the force on the underside of the piston is large enough to counterbalance the force of the spring, the piston and the poppet move upward, throttling the air passage, thus decreasing the pressure on the downstream side.
3. However, further pressure built up on the downstream side moves the piston up independently of the poppet to open the vent in the piston.



Excess air is released to the atmosphere through the vent holes until the pressure on the downstream side has dropped to an acceptable level.

4. On the other hand, when the pressure on the downstream side is low, the spring force pushes the piston and the poppet down to open the air passage which allows more high pressure air from upstream.

#### VIII. Typical nonventing pilot-controlled piston-type regulator (TM 3)

##### A. Components

1. Pilot port
2. Inlet port
3. Outlet port
4. Piston
5. Poppet
6. Air passage
7. Body

##### B. Operating principles

1. As the air pressure on the downstream side rises or drops, it is sensed on the underside of the piston.
2. When the pressure on the underside of the piston is larger than the pressure set by the pilot, the piston and the poppet move upward to throttle or close the air passage, thereby, decreasing the pressure on the downstream side.
3. On the other hand, when the pressure on the downstream side is lower than the pressure set by the pilot, the pilot pressure pushes the piston and the poppet down to open the air passage which allows more high pressure air to pass to the downstream side.

IX. Lubricator - a device which adds a controlled or measured amount of lubricant (oil) into a pneumatic system

#### X. Typical lubricator (TM 4)

##### A. Components

1. Inlet port
2. Outlet port
3. Oil adjusting screw

4. Needle valve
5. Oil channel
6. Outer air line tube
7. Inner air line tube
8. Flow guides (self-adjusting)
9. Bowl pressurizing valve
10. Oil tube
11. Bowl (transparent oil reservoir)
12. Oil

**B. Lubricator operating principles at high air flow (TM 5)**

1. Air enters lubricator and is subdivided into the following three separate flows:
  - a. Flow through the outer air line tube
  - b. Flow through the inner air line tube
  - c. Flow through bowl pressurizing valve

(NOTE: The amount of air that flows through the outer air line tube is controlled by the self-adjusting flow guides which open when the flow is high and close when the flow is low.)

2. The air which enters the inner air line tube creates a negative pressure (suction) simultaneously with the air which enters the bowl through the bowl pressurizing valve thus forcing oil out of the bowl and through the oil tube.
3. The displaced oil from the bowl drops through the oil channel to be mixed with the air which flows through the inner air line tube. The oil adjusting screw is used to control the amount of oil to be mixed by opening or closing the middle valve.
4. The moisture of oil and air meets the rest of the air on the outlet port.

**XI. Lubricator operating principles at low air flow (TM 5)**

This is similar to the principles at high air flow that are stated above, except at low air flow, the flow guides close the outer air line tube directing the flow to the inner air line tube and bowl pressurizing valve only.

LESSON PLAN: 4

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

INFORMATION TOPIC: IV-4

INTERACTION ITEMS:

1. Discuss the reasons why dust particles should be filtered from the compressed air in a pneumatic system.
2. Discuss the reasons why the compressed air in a pneumatic system should be dried.

Why is it necessary to add lubricant (oil) to the compressed air in a pneumatic system?

3. Is it always necessary to have a filter-regulator-lubricator unit in a pneumatic system? If not, when should you consider installing one?

CLASSROOM, LABORATORY, SHOP, OR OTHER ACTIVITIES:

LESSON PLAN: 4

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

INFORMATION TOPIC: IV-4

EVALUATION ITEMS:

1. List the factors which should be taken into consideration when designing or installing a filter-regulator-lubricator unit.

2.1. State the purpose of an air filter in a pneumatic system.

2.2. List four contaminant particles of air in a pneumatic system.

a.

b.

c.

d.

3. Name two types of air filters used in pneumatic systems.

a.

b.

4.1. For the typical screen-type air filter shown below, identify and write the name of each component in the space provided next to the appropriate letter.

a.

b.

c.

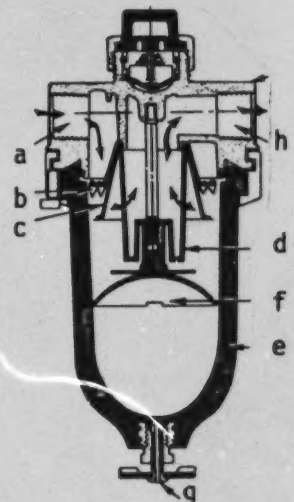
d.

e.

f.

g.

h.





4.2. With reference to the diagram shown above, discuss the operating principles of a screen-type air filter.

4.3. Name two maintenance activities which should be performed periodically for an air filter.

a.

b.

5.1. Define a regulator.

5.2. List the purposes of a regulator.

6. Name and describe two types of regulators.

a.

b.

7.1. Identify the type of regulator shown below and write the name of each component in the space next to the appropriate letter

Type of regulator \_\_\_\_\_

a.

b.

c.

d.

e.

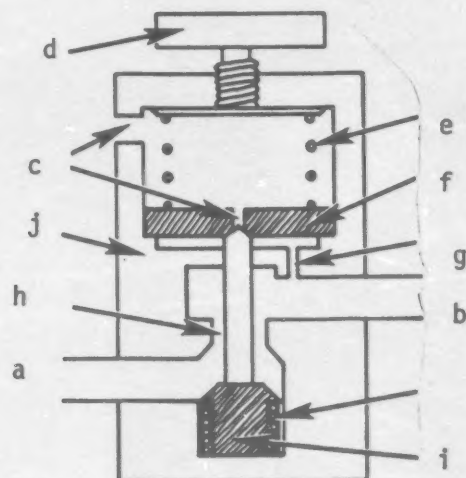
f.

g.

h.

i.

j.

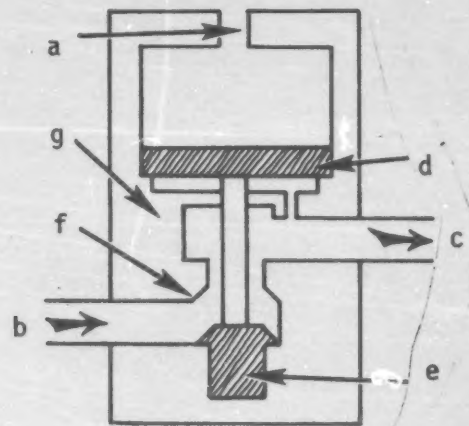


7.2. Discuss the operating principles of the regulator shown above.

- 8.1. Identify the type of regulator shown below, and write the name of each component in the space next to the appropriate letter.

Type of regulator \_\_\_\_\_

- a.
- b.
- c.
- d.
- e.
- f.
- g.

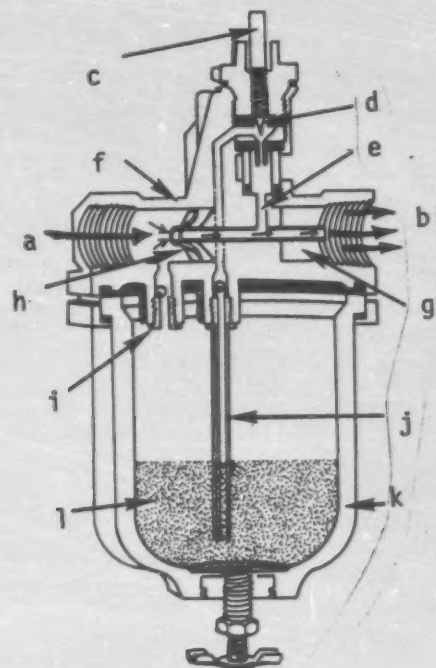


- 8.2. Discuss the operating principles of the regulator shown above.

9. Describe or state the purpose of a lubricator in a pneumatic system.

10.1. For the typical lubricator shown below, identify and write the name of each component in the space next to the appropriate letter.

- a.
- b.
- c.
- d.
- e.
- f.
- g.
- h.
- i.
- j.
- k.
- l.



10.2. With reference to the diagram shown above, discuss the operating principles of a lubricator at high air flow.

11. State the difference in the operating principles of a lubricator at high air flow and low air flow.

LESSON PLAN: 4

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

INFORMATION TOPIC: IV-4

ANSWERS TO EVALUATION ITEMS:

1. Filter-regulator-lubricator unit should be
  - a. Sized for maximum flow rate
  - b. Mounted near the point of application
  - c. Easily accessible for maintenance and operation
  - d. Provided with shut off valve upstream of the unit
  - e. Placed at a higher elevation than the point of application
- 2.1. Air filter is a device which filters or removes contaminant particles of compressed air from the receiver tank or compressor.
- 2.2.
  - a. Dust particles
  - b. Pipe scale and rust
  - c. Emulsified compressor oil droplets
  - d. Condensed water vapor
3.
  - a. Screen type
  - b. Mechanical type
- 4.1.
  - a. Inlet port
  - b. Deflector
  - c. Shrouder
  - d. Filter element or screen
  - e. Filter bowl
  - f. Baffle
  - g. Drain cock
  - h. Outlet port
- 4.2. The discussion should include:
  - a. Air from receiver tank or compressor enters inlet port.
  - b. Deflector deflects the air causing it to swirl in a circular motion.
  - c. Heavy particles and liquid drops are thrown out to the interior wall of the bowl by centrifugal force.
  - d. Heavy particles and liquid drops run down the sides of the bowl to the bottom of the bowl.
  - e. Shrouder distributes the air mass at a uniform rate across the filter element.
  - f. The filter element filters smaller particles before the air mass exits through the outlet port.



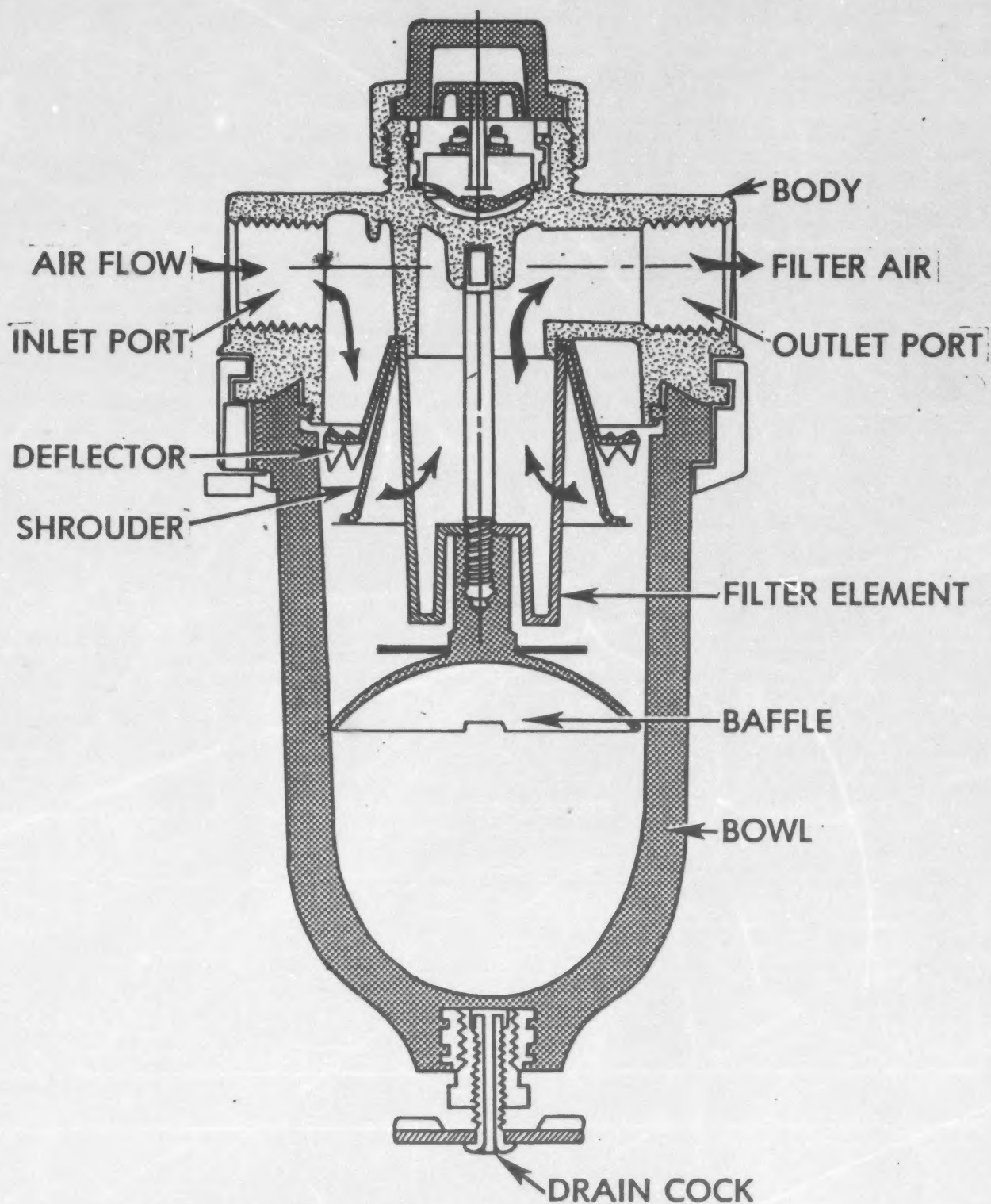
- 4.3.
  - a. Periodic draining of filtered particle, if filter drain is not automatic
  - b. Periodic replacement of filter element to avoid excessive head (pressure) resulting in loss of time.
- 5.1. A regulator is a device which provides or maintains a constant supply of pressure to the work point of a pneumatic system.
- 5.2. The purposes of a regulator include:
  - a. Maintains constant pressure regardless of the pressure fluctuation in the air line.
  - b. Saves compressed air by regulating the flow.
  - c. Reduces pressure to a level which meets work requirement.
  - d. Produces controlled pressure in systems where variable air pressure is needed.
- 6.
  - a. Venting type - the regulator releases excess air from the downstream side to equalize an excess pressure to a designated (set) working pressure requirement.
  - b. Nonventing type - the regulator equalizes an excess pressure to a designated working pressure by restricting flow of air from the upstream side.
- 7.1. Type of regulator: typical venting spring-controlled piston-type regulator components:
  - a. Inlet port
  - b. Outlet port
  - c. Vent holes
  - d. Pressure adjusting screw
  - e. Spring
  - f. Piston
  - g. Pilot passage
  - h. Air passage
  - i. Poppet
  - j. Body
- 7.2. Discussion should include:
  - a. As the pressure on the downstream rises or drops it is sensed on the underside of the piston.
  - b. When the force on the underside of the piston is large enough to counter-balance the force of the spring, the piston and the poppet move upward, throttling the air passage, thereby, decreasing the pressure on the downstream side.
  - c. However, further pressure built up on the downstream side moves the piston up independently of the poppet to open the vent in the piston. Excess air is released to the atmosphere through the vent holes until the pressure on the downstream side has dropped to an acceptable level.
  - d. On the other hand, when the pressure on the downstream side is low, the spring force pushes the piston and the poppet down to open the air passage which allows more high pressure air from upstream.

- 8.1. Type of regulator: Nonventing, pilot controlled piston type components:
- Pilot port
  - Inlet port
  - Outlet port
  - Piston
  - Poppet
  - Air passage
  - Body
- 8.2. The discussion should include:
- As the air pressure on the downstream side rises or drops, it is sensed on the underside of the piston.
  - When the pressure on the underside of the piston is larger than the pressure set by the pilot, the piston and the poppet move upward to throttle or close the air passage, thereby, decreasing the pressure on the downstream side.
  - On the other hand, when the pressure on the downstream side is lower than the pressure set by the pilot, the pilot pressure pushes the piston and the poppet down to open the air passage which allows more high pressure air to pass to the downstream side.
9. A lubricator is a device which adds a controlled or measured amount of lubricant (oil) into a pneumatic system.
- 10.1. a. Inlet port  
b. Outlet port  
c. Oil adjusting screw  
d. Needle valve  
e. Oil channel  
f. Outer air line tube  
g. Inner air line tube  
h. Flow guides (self adjusting)  
i. Bowl pressurizing valve  
j. Oil tube  
k. Bowl (transparent oil reservoir)  
l. Oil
- 10.2. Discussion should include:
- Air enters lubricator and is subdivided into three separate air flows, i.e.,
    - Flow through the outer air line pipe
    - Flow through the inner air line pipe
    - Flow through the bowl pressurizing valve
  - The air which enters the inner air line tube creates a negative pressure (suction) simultaneously with the air which enters the bowl through the bowl pressurizing valve, thus forcing oil out of the bowl and through the oil tube.
  - The displaced oil from the bowl drops through the oil channel to be mixed with the air which flows through the inner air line tube. The oil adjusting screw is used to control the amount of oil to be mixed by opening or closing the middle valve.
  - The moisture of oil and air meets the rest of the air on the outlet port.

11. Lubrication operating principles at low air flow are similar to the principles at high air flow that are stated above, except at low air flow, the flow guides close the outer air line tube directing the flow to the inner air line tube and bowl pressurizing valve only.

# AIR FILTER (SCREEN TYPE)

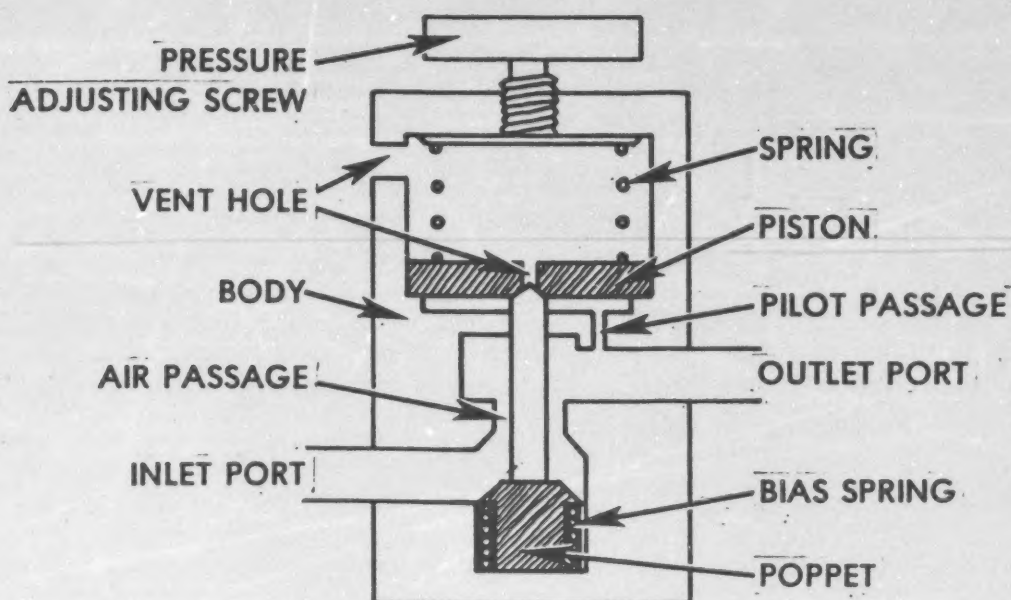
TM-1



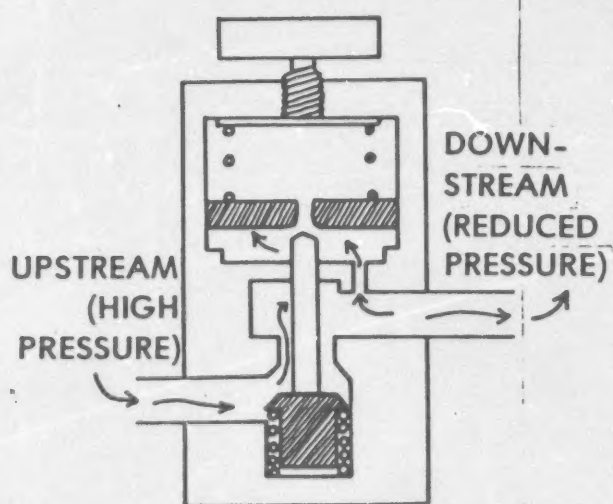


# REGULATOR (VENTING TYPE)

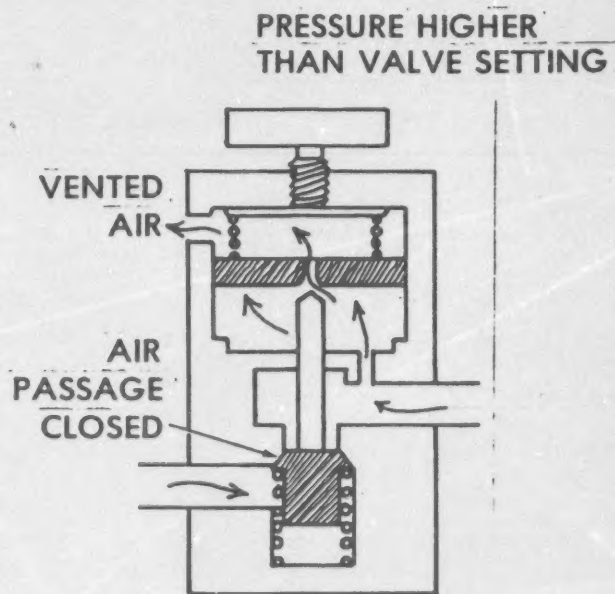
TM-2



SPRING CONTROLLED



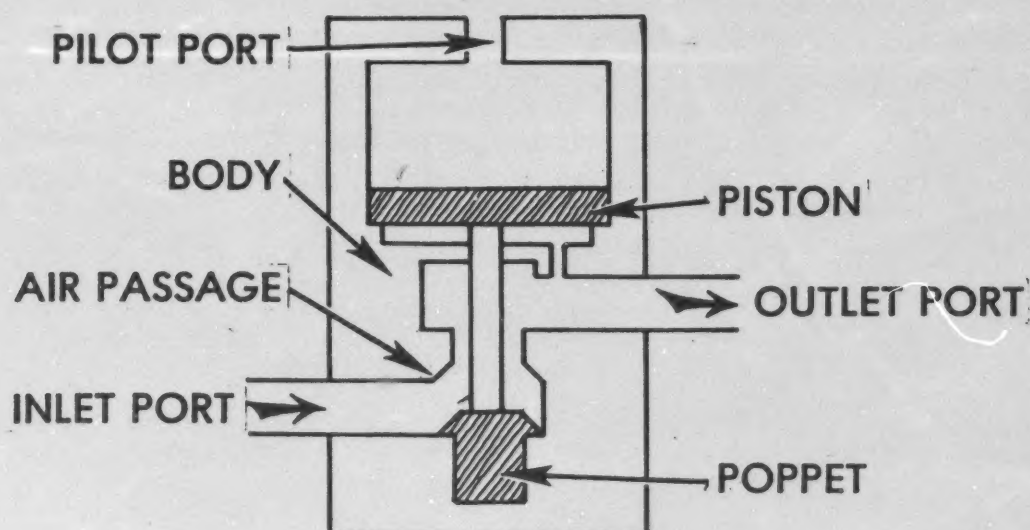
REGULATOR REGULATING



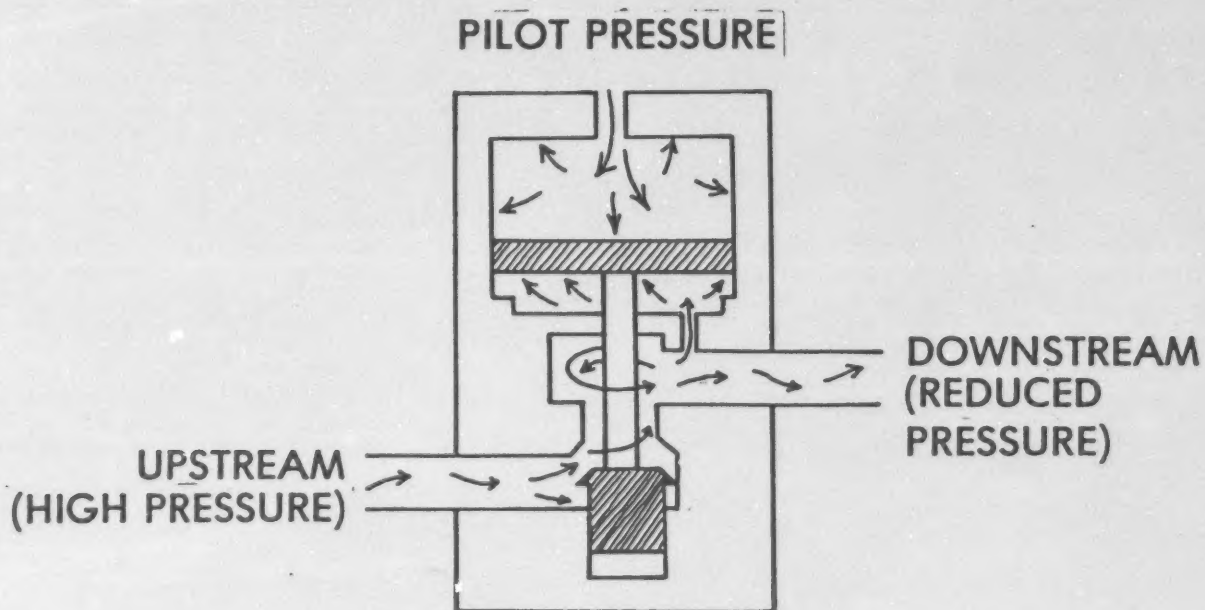
REGULATOR VENTING

# REGULATOR (NONVENTING)

TM-3

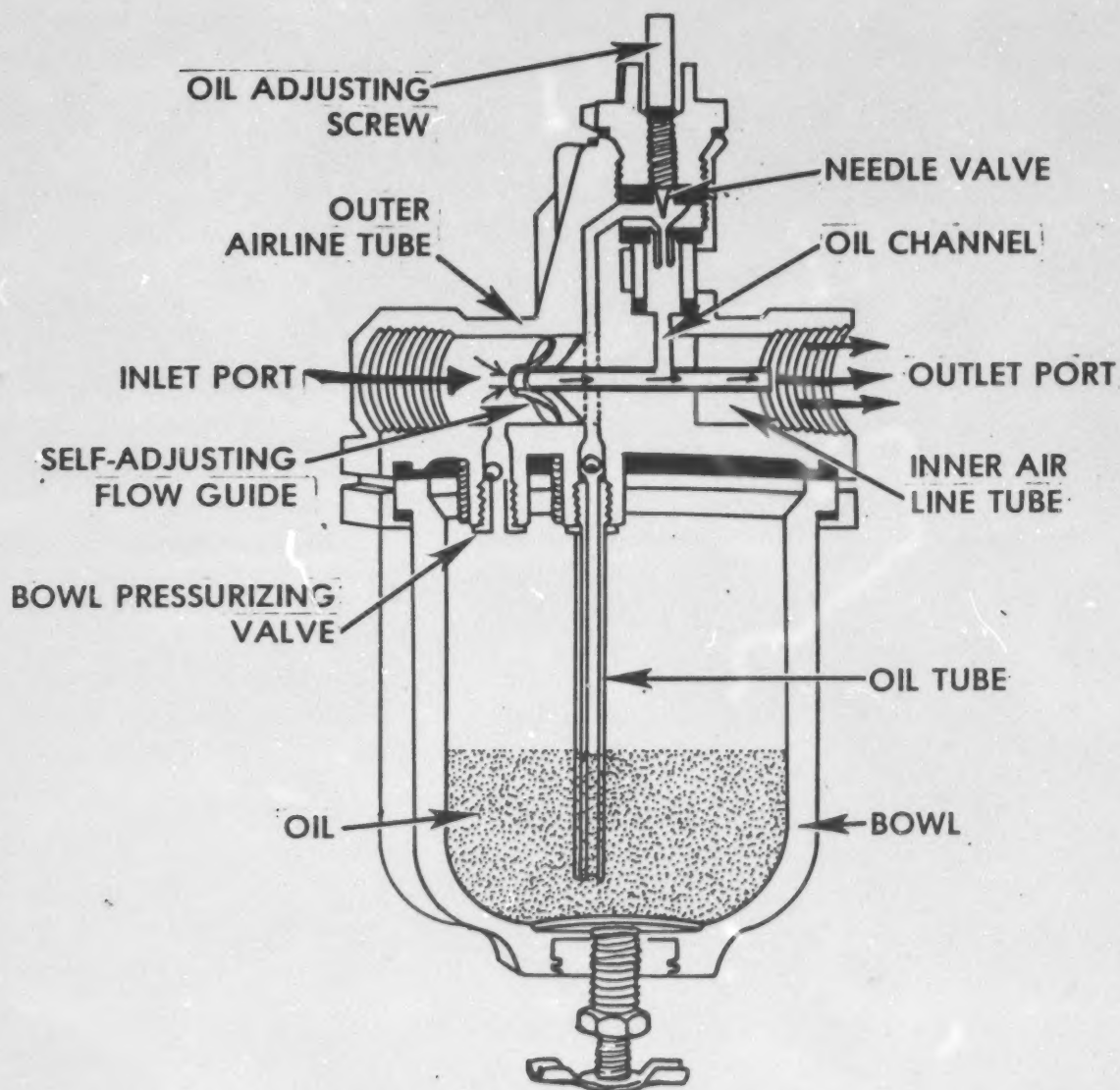


PILOT CONTROLLED

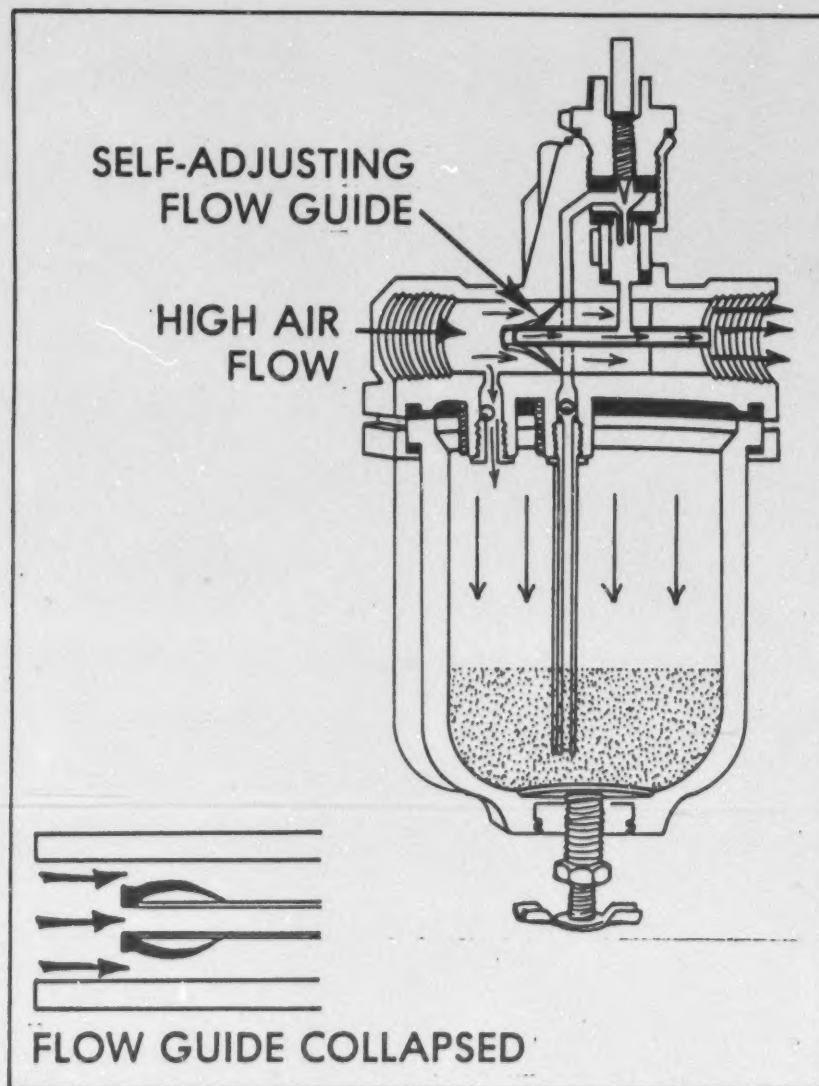


REGULATOR REGULATING

## COMPONENTS OF A TYPICAL LUBRICATOR

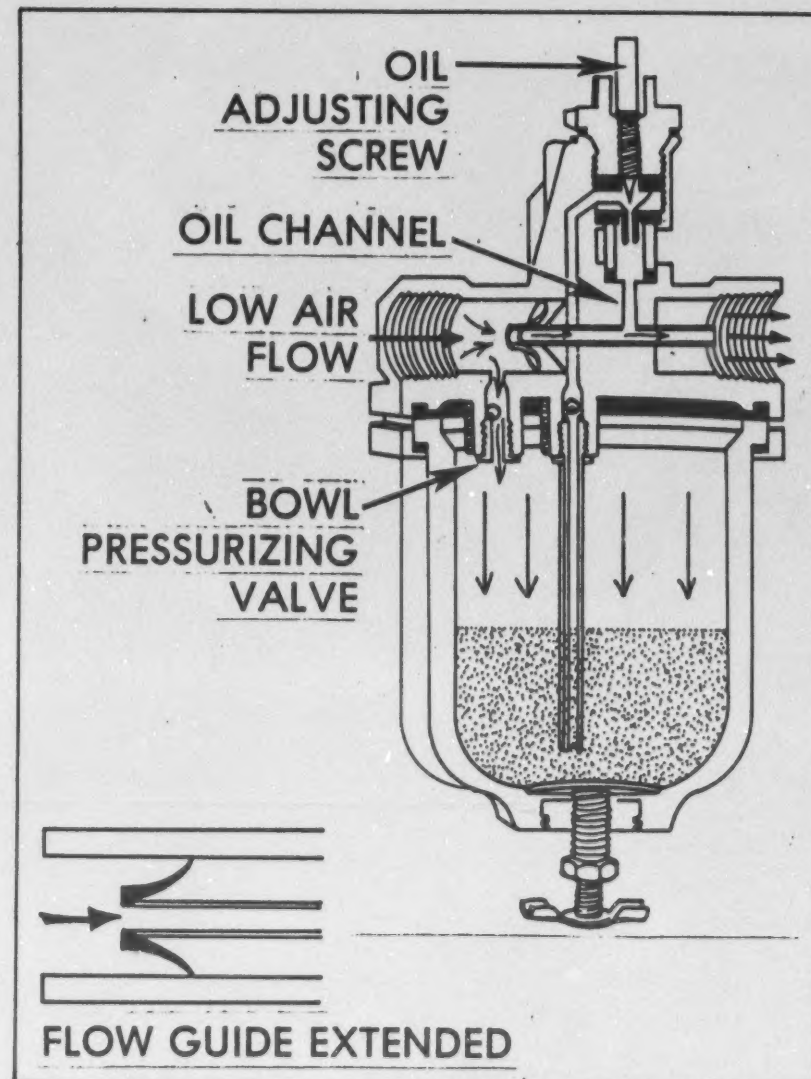


# TYPICAL LUBRICATORS



175

HIGH AIR FLOW



LOW AIR FLOW

176

TW-5



LESSON PLAN: 5

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

SCOPE OF UNIT:

After the completion of this unit, the student should be able to identify the different components which are installed for the preparation for compression and/or utilization of air in a pneumatic system. The student should be able to define or state the purposes and discuss the installation and operating principles of air intakes, noise control devices, air coolers, air driers, air receivers, air filters, regulators, and lubricators. The student should be able to disassemble, inspect and replace defective parts of an air filter.

DEMONSTRATION LESSON: IV-5

DISASSEMBLE, INSPECT, AND REASSEMBLE  
AN AIR FILTER-REGULATOR-LUBRICATOR UNIT  
(Lesson Title)

LESSON OBJECTIVES - THE STUDENT SHOULD BE ABLE TO:

1. Disassemble, inspect, identify components of, and reassemble an air filter according to the manufacturer's operating and service manual.
2. Disassemble, inspect, identify components of, and reassemble a regulator according to the manufacturer's operating and service manual.
3. Disassemble, inspect, identify components of, and reassemble a lubricator according to the manufacturer's operating and service manual.

SUPPLEMENTARY TEACHING/LEARNING ITEMS:

1. TM 1: Air Filter-Regulator-Lubricator Unit Arrangement
2. TM's 1, 2, and 3 from lesson IV 4

**INFORMATIONAL ASSIGNMENT: (Student)**

**Review Unit IV, Lesson 4: Air Filter-Regulator-Lubricator**

Review manufacturer's operating and service manual for the demonstration air filter-regulator-lubricator unit.

**REFERENCES: (Instructor's Additional Information)**

Manufacturer's operating and service manual for the demonstration air filter-regulator-lubricator unit.

**INTRODUCTION:**

Demonstrate knowledge in a hands-on application in inspection of an air filter-regulator-lubricator unit and emphasize the necessity of reviewing service manuals in the operation and maintenance of machines and their components.

LESSON PLAN: 5

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

DEMONSTRATION LESSON: IV-5

TOOLS, EQUIPMENT, AND MATERIALS:

Air filter-regulator-lubricator unit  
Service manuals, if available  
Hand tools

STEPS OF PROCEDURE: (Job Sheet)

- I. Air filter - if demonstration unit is operational, it is necessary to close the shut-off valve before proceeding to the following steps.

- A. Review manufacturer's service manual to determine the type of air filter
- B. Drain filtered particles by opening the drain cock.
- C. Disassemble air filter and identify the components.
- D. Inspect components and check if filter element needs replacement. If so, replace filter element.
- E. Reassemble.

II. Regulator

- A. Review manufacturer's service manual and fill in the appropriate information pertinent to the demonstration regulator in use.

Type of Regulator

Piston Type

Diaphragm Type

Venting

Nonventing - spring controlled

Nonventing - pilot controlled

- B. Disassemble regulator and identify the components
- C. Reassemble

III. Lubricator

- A. Review manufacturer's service manual to determine the operating principles of the demonstration lubricator

- B. Disassemble lubricator and identify the component
  - C. Reassemble
- IV. Have instructor check work on
- A. Student's use of service manual
  - B. Safety measures taken while disassembling the unit
  - C. Inspection and identification of components



LESSON PLAN: 5

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

DEMONSTRATION LESSON: IV-5

INTERACTION ITEMS: (Review Items)

1. Discuss why there should be a shut-off valve upstream of the air filter-regulator-lubricator unit.
2. Discuss why the air filter-regulator-lubricator unit should be arranged as shown in TM 1.

CLASSROOM, LABORATORY, SHOP, OR OTHER ACTIVITIES:

Review Unit IV, Lesson 4: Air Filter-Regulator-Lubricator

LESSON PLAN: 5

COURSE TITLE: BASIC PNEUMATICS

UNIT IV : COMPRESSOR ACCESSORIES

DEMONSTRATION LESSON: IV-5

EVALUATION ITEMS:

The student has satisfactorily:

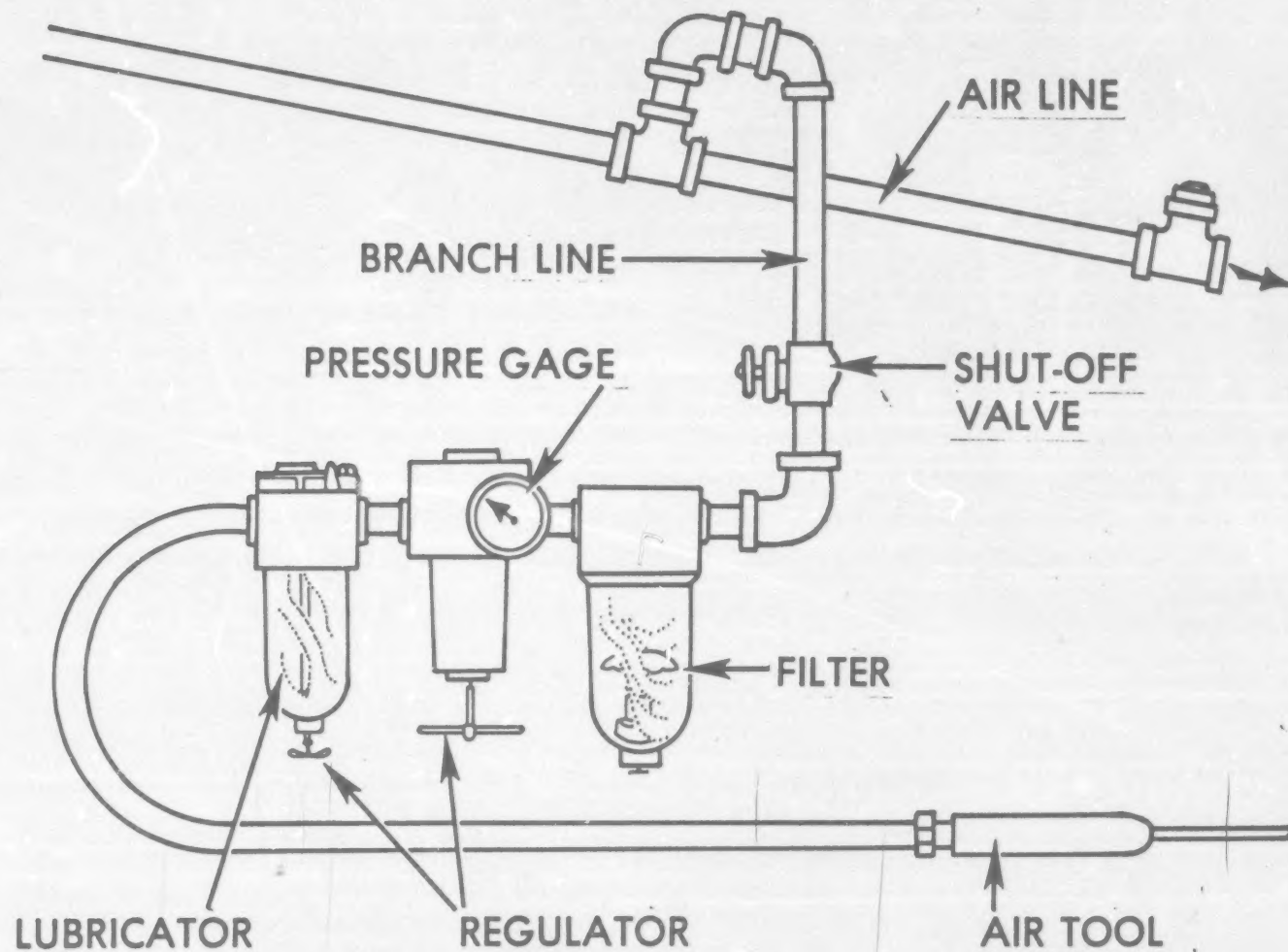
- I. Used available service manuals
- II. Practiced precaution and measures while disassembling unit
- III. Inspected and identified the components of
  - A. Air filter
  - B. Regulator
  - C. Lubricator

Yes \_\_\_\_ No \_\_\_\_

\_\_\_\_\_  
Instructor's Signature  
(Verifying Satisfactory Completion)

\_\_\_\_\_  
Date

## AIR FILTER - REGULATOR - LUBRICATOR UNIT ARRANGEMENT



LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT V : ACTUATORS

SCOPE OF UNIT:

After the completion of this unit, the student will be familiar with pneumatic actuators, which are devices that convert fluid power (air) into linear and rotational mechanical motion or force.

INFORMATION TOPIC: V-1

CYLINDERS  
(Lesson Title)

LESSON OBJECTIVES - THE STUDENT SHOULD BE ABLE TO:

1. Define and match terms related to cylinders.
2. Identify the parts of a typical cylinder.
3. Describe a single-acting cylinder and state methods of retracting its piston.
4. Describe a double-acting single rod cylinder and state the method of retracting its piston.
5. Describe a double-acting double rod cylinder, state the method of retracting its piston, and state the difference between balanced and unbalanced cylinders.
6. Discuss the operating principles of single-acting and double-acting single rod, and double-acting double rod cylinders.
7. Name some cylinder mounting methods.
8. List common causes of cylinder failure.
9. Define linear and volumetric displacement of cylinders, and given the necessary data, calculate the volumetric displacement of single-acting and double-acting cylinders.
10. Define piston travel time, piston velocity, and flow rate into a cylinder, and given the necessary data, calculate piston velocity and flow rate of single-acting and double-acting single rod and double rod cylinders.
11. Given a formula, calculate force, work and power of single-acting cylinders.
12. Given a formula, calculate the force of a double-acting cylinder.
13. Draw the symbols for single-acting and double-acting single rod and double rod cylinders.

SUPPLEMENTARY TEACHING/LEARNING ITEMS:

1. TM 1: Parts of a Typical Cylinder
2. TM 2: Types of Cylinders
3. TM 3: Some Cylinder Mounting Methods
4. TM 4: Linear Displacement, Volumetric Displacement, Piston Velocity, and Flow Rate of a Single-Acting Cylinder



5. TM 5: Linear Displacement, Volumetric Displacement, Piston Velocity, and Flow Rate of Double-Acting Single Rod Cylinder
6. TM 6: Force, Work, and Power Output of Single-Acting Cylinder
7. TM 7: Force Acting on Double-Acting Cylinder

#### INFORMATIONAL ASSIGNMENT: (Student)

IML Fluid Power/Basic Hydraulics, Lesson II-16 (Components)

Stewart, L. Harry. Pneumatics and Hydraulics. 3rd ed. Indianapolis, IN: Theodore Audel and Co., 1978.

Industrial Pneumatic Technology, Bulletin 0275-B1. Parker Hannifin Corporation, 1980.

#### REFERENCES: (Instructor's Additional Information)

IML Fluid Power/Basic Hydraulics, Lesson II-16 (Components)

Stewart, L. Harry. Pneumatics and Hydraulics. 3rd ed. Indianapolis, IN: Theodore Audel and Co., 1978.

Industrial Pneumatic Technology, Bulletin 0275-B1. Parker Hannifin Corporation, 1980.

#### INTRODUCTION:

There are times when one form of energy should be converted to another before useful work can be done. Cylinders are the actuators or machines which convert the potential energy of a pressurized fluid (air) into linear mechanical motion and force.

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT V : ACTUATORS

INFORMATION TOPIC: V-1

OUTLINE: (Key Points)

I. Terms and definitions

- A. **Actuator** - a device which converts fluid power into mechanical force and motion
- B. **Cylinder** - an actuator which converts fluid power into linear mechanical force and motion
- C. **Piston area** - area of the cylinder piston
- D. **Rod area** - area of the piston rod
- E. **Rod side area** - effective area (net area) on the rod side of the cylinder; equal to the piston area minus the rod area
- F. **Back pressure** - pressure in the return lines caused by flow restriction in these lines
- G. **Power stroke** - a stroke where high pressure air enters the cylinder to move the piston and piston rod.

II. Parts of a typical cylinder (TM 1)

- A. **Port(s)** - pressurized air inlet (outlet)
- B. **Cap end** - the cylinder end closure which completely covers the cylinder bore area
- C. **Head (load) end** - the cylinder end closure which covers the differential area between the bore area and the piston rod area.
- D. **Piston** - part of the cylinder which moves back and forth inside the cylinder
- E. **Piston rod** - a ram or plunger which transmits the force acting on the piston
- F. **Cylinder body** - the chamber or bore
- G. **Cushion** - a device which provides controlled resistance to the motion of the piston and piston rod.
- H. **Piston seal** - a device which prevents or controls the escape of fluid (air) between the piston and cylinder wall.

- I. Rod seal - a device which prevents or controls the escape of fluid through the periphery of the piston rod
- J. Rod gland bushing - a device which centers or keeps the piston rod in position.
- K. Mount - a device by which a cylinder is connected or fastened to its mating element

### III. Single-acting cylinder

- A. A cylinder in which the pressure is applied to the movable element (piston) in one direction and force is transmitted in the other direction (TM 2A)
- B. Methods of piston retraction (return)
  - 1. Spring return - a spring is used to retract the piston to its starting position after the end of the power stroke.
  - 2. Gravity return - the weight of the piston and/or other weight retracts the piston to its starting position.

### IV. Double-acting, single rod cylinder

- A. A cylinder in which pressure is applied to the movable element in both directions and force is transmitted in only one direction. (TM 2B)
- B. Method of piston return: piston retracts to its starting position when the flow of air is directed to enter cylinder from the head (rod) end side.

### V. Double-acting, double rod cylinder

- A. A cylinder in which the pressure is applied to the movable element in both directions and force is transmitted in both directions (TM 2C)
- B. Method of piston return: piston retracts in either direction when the air is allowed to enter from the opposite direction.

(NOTE: Double-acting cylinders can be either balanced or unbalanced. A balanced double-acting cylinder has an equal area on both sides of the piston. An unbalanced double-acting cylinder has unequal areas on each side of the piston.)

### VI. Operation of single-acting and double-acting cylinders

- A. Single-acting
  - 1. Compressed air flows into only one side of the cylinder.
  - 2. Pressure of the fluid acting on the surface of the piston creates a force causing the piston and piston rod to move in one direction.
  - 3. The piston is retracted to its starting position by a spring or gravity.
- B. Double-acting (both single and double rod)

1. Compressed air flows into one side of the cylinder.
2. Pressure of the fluid acting on one side of the piston creates a force, causing the piston and piston rod to move in one direction.
3. The piston is retracted by air flow into the other side of the cylinder.

VII. Some cylinder mounting methods (TM 3)

- A. Cap fixed clevis - a cylinder mounting consisting of a clevis integral with the cap to maintain a fixed clevis-port relationship
- B. Cap trunnion - a cylinder mounting consisting of a trunnion near or at the cap end of the cylinder
- C. Cap square flange - a cylinder mounting consisting of a supplementary square flange plate
- D. Side lug - a side mounting consisting of one or more lugs at the ends of the cylinder facing a common side

(NOTE: The student should be aware that there are many other methods of cylinder mounting each having its specific merits and applications.)

VIII. Common causes of failure of a cylinder

- A. Dirt in the system may cause scouring of the cylinder walls, piston, and piston rod.
- B. Heat may cause seizure of close-fitting metal parts and deterioration of packing and seals.
- C. Lack of lubricant
- D. Broken spring (in single-acting cylinder)
- E. Excessive operating pressure may cause early deterioration of packing
- F. Buckling of piston rods

IX. Cylinder displacement

- A. Linear displacement (L) is the distance traveled by the piston in one stroke.
- B. Volumetric displacement (V) is the amount of fluid entering the cylinder chamber in one stroke

1. Single-acting (TM 4)

Volumetric displacement =  $V = \text{Piston Area (A)} \times \text{linear displacement (L)}$ , so  $V = AL$



Example: Calculate the volumetric displacement (V) of a single acting cylinder, if the piston diameter (D) is 4 inches and the linear displacement (L) is 6 inches

Piston linear displacement =  $L = 6 \text{ in.} = 0.5 \text{ ft.}$

Volumetric displacement =  $V = AL = 0.0872 \text{ sq. ft.} \times 0.5 \text{ ft.} = 0.0436 \text{ cf.}$

2. Double-acting, single end rod (TM 5)

a. Piston extending -

Volumetric displacement =  $V = \text{Piston Area (A)} \text{ times linear displacement (L), so } V = AL$

b. Piston retracting -

Volumetric displacement =  $V = \text{Cylinder effective area (A}_e\text{)} \text{ times linear displacement (L), so } V = A_e L = (A - A_r)L$

where  $A_e = \text{Piston area, } A = \text{Piston rod area, } A_r.$

(NOTE: Volumetric displacement V differs when piston is extending and retracting.)

Example: Determine the volumetric displacement V of a double-acting single rod cylinder if the piston diameter (D) is 1 inch and the linear displacement (L) of the cylinder is 6 inches.

a. Piston extending:

Piston linear displacement =  $L = 6 \text{ in.} = 0.5 \text{ ft.}$

Piston area =  $A = \left(\frac{\pi}{4}\right) D^2 = \left(\frac{\pi}{4}\right) \left(\frac{4}{12}\right)^2 = 0.0872 \text{ sq. ft.}$

Volumetric displacement =  $V = AL = 0.0872 \text{ sq. ft.} \times 0.5 \text{ ft} = 0.0436 \text{ CF.}$

b. Piston retracting:

Piston linear displacement =  $L = 6 \text{ in.} = 0.5 \text{ ft}$

Piston area =  $A = \left(\frac{\pi}{4}\right) D^2 = \left(\frac{\pi}{4}\right) \left(\frac{4}{12}\right)^2 = 0.0872 \text{ sq. ft}$

Piston rod area =  $A_r = \left(\frac{\pi}{4}\right) (d)^2 = \left(\frac{\pi}{4}\right) \left(\frac{1}{12}\right)^2 = 0.0055 \text{ sq. ft.}$

Volumetric displacement =  $V = A_e L = (A - A_r)L = (0.0872 - 0.0055) \times 0.5 = 0.0408 \text{ CF}$

(NOTE: In the above calculations, if the areas are calculated in square feet L should be in feet and V is determined in cubic feet (cf).

X. Piston travel time, piston velocity, and flow rate

- A. Piston travel time ( $t$ ) is the time required for the piston to travel from the starting position to the end of the power stroke.
- B. Piston velocity ( $v_p$ ) is the speed of the piston and is equal to the piston linear displacement ( $L$ ) divided by the piston travel time ( $t$ ).

$$v_p = \frac{L}{t}$$

(NOTE: Additional methods of determining piston velocity will be given in section XI.)

Example: If the linear displacement  $L$  of a cylinder is 6 inches and the piston travel time  $t$  is 5 seconds, determine the piston velocity  $v_p$ .

Linear displacement =  $L = 6 \text{ in} = 0.5 \text{ ft}$

Piston travel time =  $t = 5 \text{ sec.}$

$$v_p = \frac{L}{t} = \frac{0.5}{5} = 0.1 \text{ ft/sec}$$

- C. Rate of flow ( $Q$ ) of a cylinder is the rate of fluid (air) entering the cylinder to move the piston a given distance in a given time. In general, rate of flow  $Q = (\text{Volumetric Displacement } V)/(\text{Piston travel time})$

1. Single-acting (TM 4)

$$\text{Rate of flow} = Q = \frac{V}{t}$$

$$\text{or } Q = \frac{AL}{t}$$

$$\text{or } Q = A v_p$$

Where  $A$ ,  $L$ ,  $t$ ,  $v_p$  are as defined earlier.

Example: For a single-acting cylinder determine the flow rate  $Q$  required to move a cylinder piston through a distance of 6 inches (linear displacement) in 5 seconds (piston travel time) if the piston diameter is 4 inches.

Distance travelled = Piston linear displacement =  $L = 6 \text{ in.} = 0.5 \text{ ft}$

Piston travel time =  $t = 5 \text{ sec.}$

$$\text{Piston area} = A = \left(\frac{\pi}{4}\right)D^2 = \left(\frac{\pi}{4}\right)\left(\frac{4}{12}\right)^2 = 0.0872 \text{ sq. ft.}$$

$$\text{Flow rate} = Q = \frac{AL}{t} = \frac{(0.0872 \text{ sq. ft.} \times 0.5 \text{ ft})}{5 \text{ sec.}} = 0.00872 \text{ CFS}$$

(NOTE: If the flow rate  $Q$  is given or known, piston velocity  $v_p$  can be calculated by  $v_p = \frac{Q}{A}$ )

for the above example,  $v_p = \frac{Q}{A} = 0.1 \text{ ft./sec.}$

2. Double-acting, single rod (TM 5)

a. Piston extending:

$$\text{Rate of flow} = Q = \frac{V}{t}$$

$$\text{Where, } V = AL$$

$$\text{or } Q = Av_p$$

b. Piston retracting:

$$\text{Rate of flow} = Q = \frac{V}{t}$$

$$\text{Where, } V = (A - A_r)L \text{ or } Q = (A - A_r)v_p$$

Where  $A$ ,  $A_r$ ,  $L$ ,  $t$ , and  $v_p$  are as defined above.

Example: For a double-acting, single rod cylinder, determine the flow rate  $Q$  required to move the piston through a distance of 6 inches in 5 seconds when the piston is extending and retracting if the piston diameter is 4 inches and the rod diameter is 1 inch.

$$\text{Distance travelled} = \text{Linear displacement} = L = 6 \text{ in} = 0.5 \text{ ft}$$

$$\text{Piston travel time} = t = 5 \text{ sec}$$

$$\text{Piston area} = A = \frac{\pi}{4}(D^2) = \left(\frac{\pi}{4}\right)\left(\frac{4}{12}\right)^2 = 0.0872 \text{ sq. ft.}$$

$$\text{Piston rod area} = A_r = \frac{\pi}{4}(d)^2 = \left(\frac{\pi}{4}\right)\left(\frac{1}{12}\right)^2 = 0.0055 \text{ sq. ft.}$$

$$\text{Piston extending, } Q = \frac{AL}{t} = \frac{(0.0872 \text{ sq. ft.} \times 0.5 \text{ ft})}{5 \text{ sec}} = 0.00872 \text{ cfs}$$

$$\text{Piston retracting, } Q = \frac{(A - A_r)L}{t} = \frac{(0.0872 - 0.0055) \times 0.5}{5} = 0.00816 \text{ cfs}$$

(Note the difference in flow rates when the piston is extending and retracting.)

3. Double-acting, double rod

a. Balanced:

$$\text{Rate of flow } Q = \frac{V}{t}$$

where  $V = (A - A_r) L$

or  $Q = (A - A_r) v_p$

- b. Unbalanced: This is similar to the above except the correct value of  $A_r$  should be used when the piston is extending and retracting.

XI. Force, work, and power output (horsepower) of single-acting (TM 6)

A. Force = Pressure x Piston Area, or  $F = PA$

Example: Calculating force when pressure and area are known

Pressure =  $P = 1500$  psi

Piston diameter =  $D = 3.0$  inches

(NOTE:  $\pi = 3.14$ )

$$\text{Piston area} = A = \frac{\pi D^2}{4} = \frac{3.14 (3)^2}{4} = 7.07 \text{ sq. in.}$$

$$\text{Force} = F = 1500 \text{ lbs./sq. in.} \times 7.07 \text{ sq. in.} = 10,600 \text{ lbs.}$$

Example: Calculating pressure when force and diameter are known

Force = 5,000 lbs.

Piston Diameter = 2.0 inches

$$\text{Piston area} = A = \frac{\pi D^2}{4} = \frac{3.14 (2^2)}{4} = 3.14 \text{ sq. in.}$$

$$\text{Pressure} = P = \frac{F}{A} = \frac{5,000 \text{ lbs.}}{3.14 \text{ sq.in.}} = 1590 \text{ psi}$$

B. Work = Force x Distance travelled by the force, or  $W = FL$

Since  $F = PA$  and volumetric displacement  $V = AL$ , work can be expressed as  $W = PAL = PV$  also.

(NOTE: In cylinders, the distance travelled by the force is equal to the linear displacement of the piston.)

C. Power = work divided by the time required to do the work or  $\text{Power} = \frac{W}{t}$

In addition, power can be calculated by the following formulas:

1. If pressure  $P$ , piston area  $A$ , and linear displacement  $L$  and travel time  $t$  are known,  $\text{Power} = \frac{PAL}{t}$
2. If piston velocity  $v_p$  and force  $F$  acting on the piston are known,  $\text{Power} = v_p F$



D. Power in horsepower (HP) is determined by

$$\text{Power (horsepower)} = \text{hp} = \frac{v_p F}{33,000}$$

Where  $v_p$  = rod velocity (ft./min.)  
 $F$  = rod force (pounds force)

$$\text{or Power (horsepower)} = \text{hp} = \frac{v_p F}{550}$$

where  $v_p$  = rod velocity (ft./sec.)  
 $F$  = rod force (pounds force)

Example: Calculate the power (horsepower) of a single-acting cylinder if the pressure  $P$  acting on the piston is 1500 psi, piston diameter  $D$  is 3 inches, the linear displacement of the piston is 6 inches and piston travel time is 5 seconds.

Piston (or force) travelled distance =  $L = 6 \text{ in} = 0.5 \text{ ft.}$   
Piston travel time =  $t = 0 \text{ sec.} = 0.1 \text{ minutes}$

$$\text{Piston area} = A = \frac{\pi D^2}{4} = \frac{3.14 \times 3^2}{4} = 7.07 \text{ sq. in.}$$

Pressure acting on the piston =  $P = 1500 \text{ psi}$

Force acting on the piston =  $F = PA = 1500 \text{ lbs./sq. in.} \times 7.07 \text{ sq. in.} = 10,600 \text{ lbs.}$

Work =  $W = FL = 10,600 \text{ lb} \times 0.5 \text{ ft} = 5,300 \text{ ft. lbs.}$

$$\text{Power} = \frac{W}{t} = \frac{5300 \text{ ft. lbs.}}{0.1 \text{ min}} = 53,000 \text{ ft.lbs./min}$$

$$\text{Power, hp} = \frac{53,000 \text{ ft.lbs.}}{33,000 \text{ ft.lbs./hp}} = 1.6 \text{ hp}$$

Alternative solution:

Force acting on the piston =  $F = PA = 1500 \text{ lbs./sq. in.} \times 7.07 \text{ sq. in.} = 10,600 \text{ lbs}$

$$\text{Piston velocity} = v_p = \frac{L}{t} = \frac{0.5 \text{ ft}}{6 \text{ sec.}} = \frac{0.5 \text{ ft}}{0.1 \text{ min}} = 5 \text{ ft/min}$$

$$\text{Power (horsepower)} = \frac{(v_p F)}{33,000} = \frac{10,600 \times 5}{33,000} = 1.6 \text{ hp.}$$

## XII. Force of a double-acting cylinder (TM 7)

- A. Force = Piston Area x Piston Pressure - Rod-side Area x Rod-side pressure

$$AP_c - ArPr$$

Example: Piston diameter = 4 inches

Rod diameter = 2 inches

Piston pressure =  $P_c$  = 1500 pounds per square inch (psi)

Rod-side pressure =  $P_r$  = 500 pounds per square inch (psi)

$$\text{Piston area} = \frac{\pi D^2}{4} = \frac{3.14 (4)^2}{4} = 12.6 \text{ sq. in.}$$

$$\text{Rod area} = \frac{(3.14) (2)^2}{4} = 3.14 \text{ sq. in.}$$

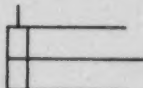
$$\text{Rod-side area} = 12.56 - 3.14 = 9.42 \text{ sq. in.}$$

$$F = (1500 \text{ lbs./sq. in.}) \times (12.6 \text{ sq. in.}) - (500 \text{ lbs./sq. in.}) (9.42 \text{ sq. in.})$$

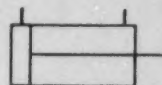
$$F = 14,190 \text{ lbs.}$$

## XIII. Symbols for cylinders

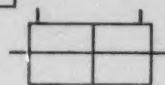
- A. Single-acting



- B. Double-acting, single rod



- C. Double-acting, double rod



LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT V: ACTUATORS

INFORMATION TOPIC: IV-1

INTERACTION ITEMS:

1. In what position should a cylinder be mounted if gravity will be used to retract the piston of a single-acting cylinder?
2. Which of the double-acting cylinders can be balanced and which cannot be balanced?
3. In a balanced double-acting, double rod cylinder, the volumetric displacement of the piston moving in either direction is equal. Why?

CLASSROOM, LABORATORY, SHOP, OR OTHER ACTIVITIES:

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT V : ACTUATORS

INFORMATION TOPIC: V-I

EVALUATION ITEMS:

I. Match the terms on the right with the correct definitions.

- |        |                                                                                             |    |               |
|--------|---------------------------------------------------------------------------------------------|----|---------------|
| ___ a. | Area of the piston rod                                                                      | 1. | Piston area   |
| ___ b. | Area of the cylinder piston                                                                 | 2. | Back pressure |
| ___ c. | Effective area on the rod side of the cylinder; equal to the piston area minus the rod area | 3. | Rod area      |
|        |                                                                                             | 4. | Rod side area |
| ___ d. | An actuator which converts hydraulic power into linear mechanical force and motion          | 5. | Cylinder      |
|        |                                                                                             | 6. | Actuator      |
| ___ e. | Pressure in the return lines caused by flow in these lines                                  | 7. | Power stroke  |
| ___ f. | A device which converts fluid power into mechanical force and motion                        |    |               |
| ___ g. | A stroke where a high pressure air enters the cylinder to move the piston and piston rod    |    |               |



2. Identify the parts of the cylinder shown below.

a.

b.

c.

d.

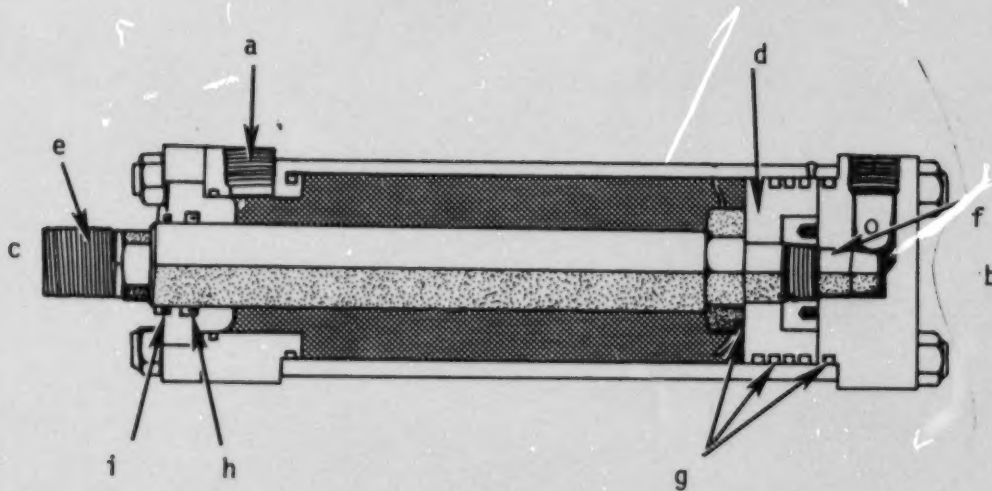
e.

f.

g.

h.

i.



3. Describe a single-acting cylinder and state its method(s) of piston return.
4. Describe a double-acting single rod cylinder and state the method of retracting its piston.
- 5.1. Describe a double-acting double rod cylinder and state the method of retracting its piston.
- 5.2. State the difference between balanced and unbalanced double-acting cylinders.
- 6.1. Discuss the operation of a single-acting cylinder.
- 6.2. Discuss the operation of a double-acting cylinder.
7. Name and describe four cylinder mounting methods.
  - a.
  - b.
  - c.
  - d.
8. List at least four common causes of failure of a cylinder.
  - a.
  - b.
  - c.
  - d.
- 9.1. Define linear displacement of a cylinder.
- 9.2. Define volumetric displacement of a cylinder.

9.3. Calculate the volumetric displacement  $V$  of a single-acting cylinder, if the piston diameter  $D$  is 4 inches and the linear displacement ( $L$ ) is 12 inches.

9.4. Determine the volumetric displacement  $V$  of a double-acting single rod cylinder, if the piston diameter  $D$  is 3 inches, rod diameter  $d$  is 1 inch and the linear displacement ( $L$ ) is 15 inches.

a. Piston extending

b. Piston retracting

10.1. Define piston travel time.

10.2. Define piston velocity.

10.3. If the linear displacement of a cylinder is 15 inches and piston travel time is 10 sec., what is the piston velocity in feet per second?

10.4. Define the rate of flow of a cylinder.

10.5. For a single-acting cylinder, determine the flow rate  $q$  required to move a 6 inch diameter piston through a distance of 12 inches in 6 seconds (solve in three alternative ways).

10.6. For a double-acting, single rod cylinder, determine the flow rate  $Q$  required to move a 6 inch diameter piston and a 1 inch diameter rod through a distance of 12 inches in 6 seconds (Make sure to determine  $Q$  when the piston is extending and retracting.)

10.7. For a double-acting, double rod cylinder, determine the flow rate  $Q$  required to move a 6 inches diameter piston and 1 inch diameter rods through a distance of 15 inches in 10 seconds. (Note that the cylinder is a balanced double-acting cylinder.)

11.1. Force = \_\_\_\_\_ x \_\_\_\_\_

11.2. Calculate the force acting on a single-acting cylinder, if the diameter of the piston is 4 inches and the pressure is 1000 psi.

11.3. Work = \_\_\_\_\_ x \_\_\_\_\_

11.4. Determine the work done by a single-acting cylinder, if the diameter of the piston is 4 inches, the pressure acting on the piston is 1000 psi and the linear displacement of the piston is 15 inches.

11.5. In general, Power = \_\_\_\_\_ / \_\_\_\_\_

11.6. If rod or piston velocity is in ft./min. and rod force is in pounds force, then

$$\text{Power (horsepower)} = ( \text{_____} \times \text{_____} ) / \text{_____}$$

11.7. If rod or piston velocity is in ft./sec. and rod force is in pounds force, then

$$\text{Power (horsepower)} = ( \text{_____} \times \text{_____} ) / \text{_____}$$

11.8. Determine the power (horsepower) of a single-acting cylinder, if the diameter of the piston is 4 inches, pressure acting on the piston is 1000 psi, and the piston linear displacement is 15 inches in 10 seconds.

12.1. For a double-acting, single rod cylinder,

$$\text{Force} = ( \text{_____} \times \text{_____} ) - ( \text{_____} \times \text{_____} )$$

12.2. Calculate the force of a double-acting, single rod cylinder, given that

Piston diameter = 6 inches

Rod diameter = 2 inches

Piston pressure = 1000 psi

Rod-side pressure = 400 psi.

13. Draw the symbol for:

- a. Single-acting cylinder
- b. Double-acting, single rod cylinder
- c. Double-acting, double rod cylinder



LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT V : ACTUATORS

INFORMATION TOPIC: IV-1

ANSWERS TO EVALUATION ITEMS:

1.
  - a. 3
  - b. 1
  - c. 4
  - d. 5
  - e. 2
  - f. 6
  - g. 7
2.
  - a. Port
  - b. Cap end
  - c. Head end
  - d. Piston
  - e. Piston rod
  - f. Cushion
  - g. Piston seal
  - h. Rod seal
  - i. Rod gland bushing
3. Single-acting - a cylinder in which the pressure is applied to the movable element (piston) in one direction and force is transmitted in the other direction
  - 1) Methods of piston retraction (return)
    - a. Spring return - a spring is used to retract the piston to its starting position after the end of the power stroke
    - b. Gravity return - the weight of the piston and/or other weight retracts the piston to its starting position
4. Double-acting, single rod cylinder - a cylinder in which pressure is applied to the movable element in both directions and force is transmitted in only one direction.

Method of piston return: piston retracts to its starting position when the flow of air is directed to enter cylinder from the head (rod) end side.
- 5.1. Double-acting, double rod cylinder - a cylinder in which the pressure is applied to the movable element in both directions and force is transmitted in both directions

Method of piston return: piston retracts in either direction when the air is allowed to enter from the opposite direction.

- 5.2. Balanced double-acting cylinders have an equal area on both sides of the piston.  
Unbalanced double-acting cylinders have unequal areas on each side of the piston.
- 6.1. Discussion should include:
  - a. Compressed air flows into only one side of the cylinder.
  - b. Pressure of the fluid acting on the surface of the piston creates a force causing the piston and piston rod to move in one direction
  - c. The piston is retracted to its starting position by a spring or gravity
- 6.2. Double-acting (both single and double rod)
  - a. Compressed air flows into one side of the cylinder.
  - b. Pressure of the fluid acting on one side of the piston creates a force, causing the piston and piston rod to move in one direction
  - c. The piston is retracted by air flow into the other side of the cylinder.
7.
  - a. Cap fixed clevis is a cylinder mounting consisting of a clevis integral with the cap to maintain a fixed clevis-port relationship
  - b. Cap trunnion is a cylinder mounting consisting of a trunnion near or at the cap end of the cylinder
  - c. Cap square flange is a cylinder mounting consisting of a supplementary square flange plate
  - d. Side lug is a side mounting consisting of one or more lugs at the ends of the cylinder facing a common side.
8.
  - a. Dirt
  - b. Heat
  - c. Lack of lubricant
  - d. Broken spring
  - e. Excessive operating pressure
  - f. Buckling of piston rods
- 9.1. Linear displacement (L) is the distance traveled by the piston in one stroke.
- 9.2. Volumetric displacement (V) is the amount of fluid entering the cylinder chamber in one stroke
- 9.3. Volumetric displacement = 0.087 cubic feet
- 9.4. Piston extending: volumetric displacement = 0.061 cubic feet  
Piston retracting: volumetric displacement = 0.055 cubic feet
- 10.1. Piston travel time (t) is the time required for the piston to travel from the starting position to the end of the power stroke.
- 10.2. Piston velocity ( $v_p$ ) is the speed of the piston and is equal to the piston linear displacement L divided by the piston travel time t.
- 10.3. Piston velocity = 0.125 ft./sec. = 7.5 ft./min.
- 10.4. Rate of flow (Q) of a cylinder is the rate of fluid (air) entering the cylinder to move the piston a given distance in a given time.

10.5. Rate of flow = 0.0327 cubic feet per second (cfs) = 1.962 cubic feet per minute (cfm)

10.6. Piston extending:

Rate of flow = 0.0327 cfs = 1.962 cfm

Piston retracting:

Rate of flow = 0.0318 cfs = 1.908 cfm

10.7. In both directions, flow rate = 0.0238 cfs = 1.431 cfm

11.1. Force = Pressure x Piston area

11.2. Force = 12,560 lbs.

11.3. Work = Force x Distance travelled by the force

11.4. Work = 15,700 ft.-lbs.

11.5. Power = work/time required to do the work

11.6. Power (horsepower) = (Rod velocity x Rod force)/33,000

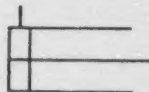
11.7. Power (horsepower) = (Rod velocity x Rod force)/550

11.8. Power (horsepower) = 28.55 hp

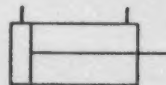
12.1. Force = (Piston area x Piston pressure) - (Rod side area x Rod side pressure)

12.2. Force = 27,004 lbs.

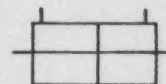
13. a. Single-acting



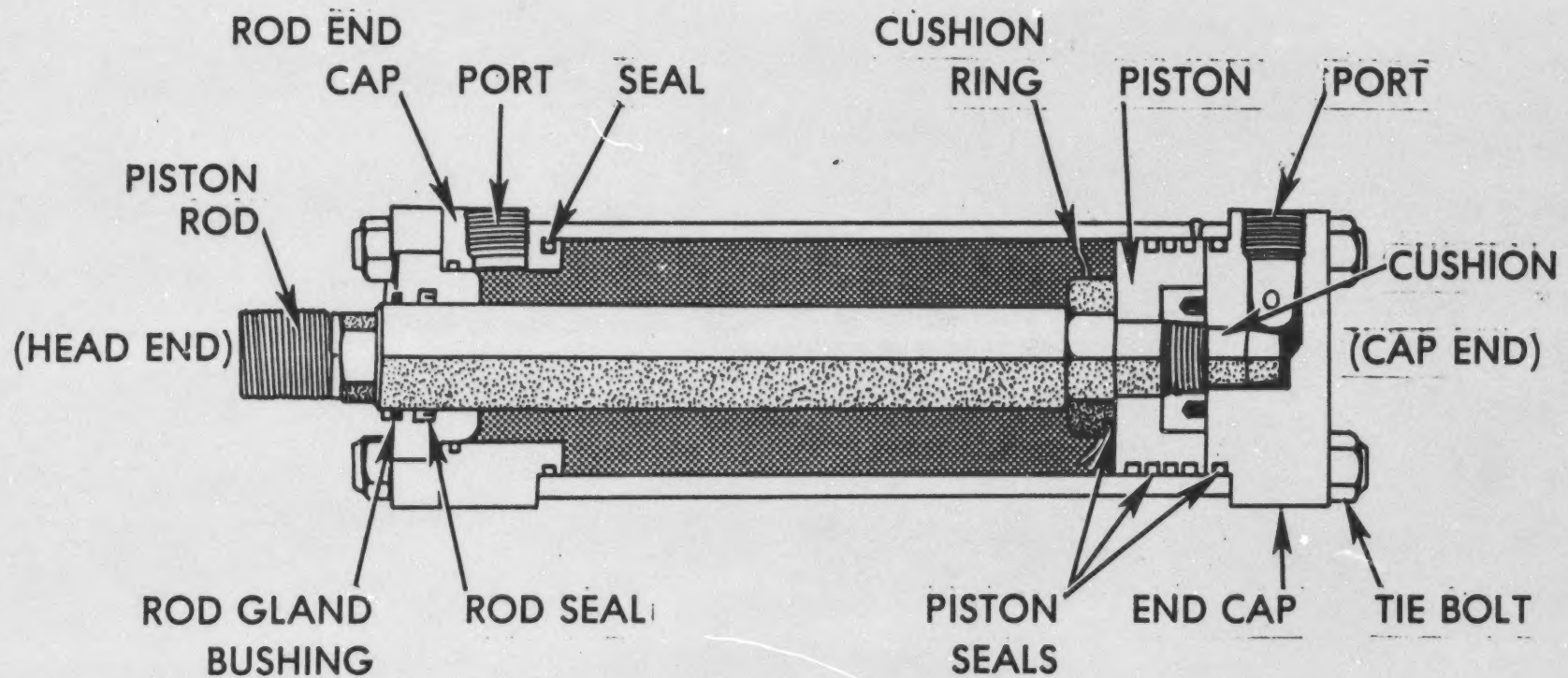
b. Double-acting single rod



c. Double-acting double rod



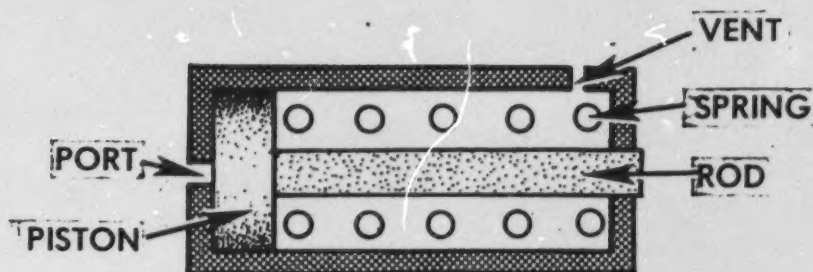
## PARTS OF A TYPICAL CYLINDER





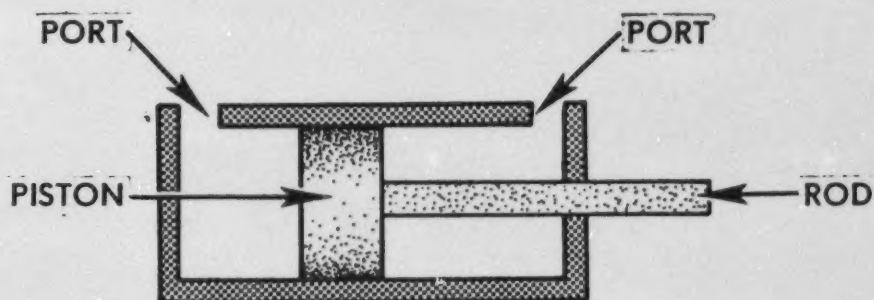
# TYPES OF CYLINDERS

TM-2



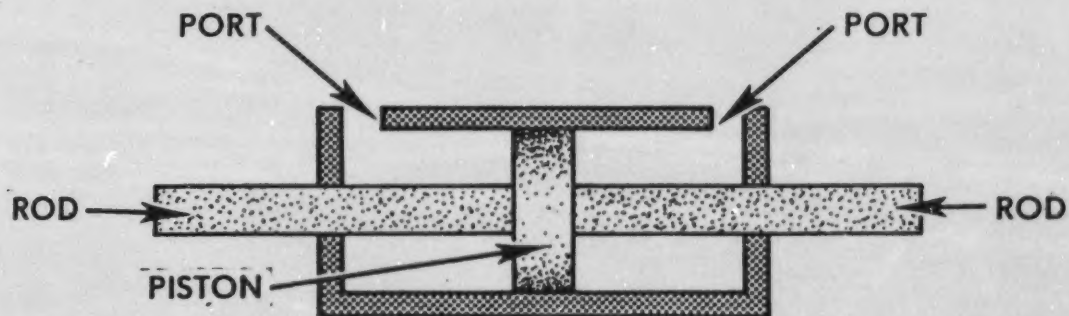
A. SINGLE-ACTING CYLINDER

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B. DOUBLE-ACTING SINGLE ROD CYLINDER

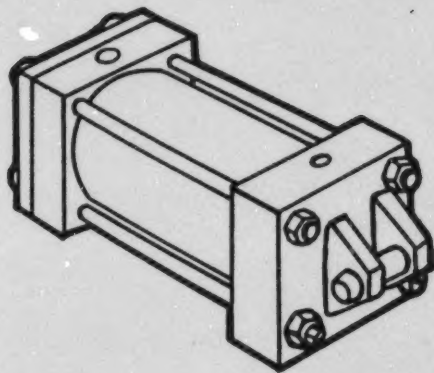
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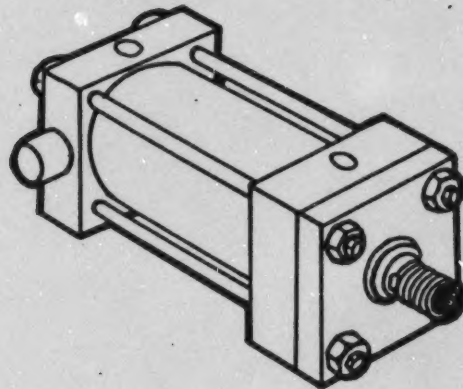
C. DOUBLE-ACTING DOUBLE ROD CYLINDER

# SOME CYLINDER MOUNTING METHODS

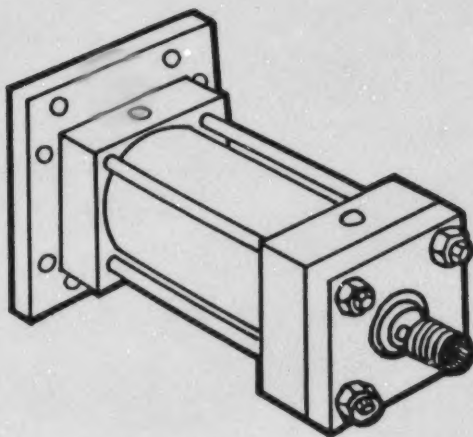
TM-3



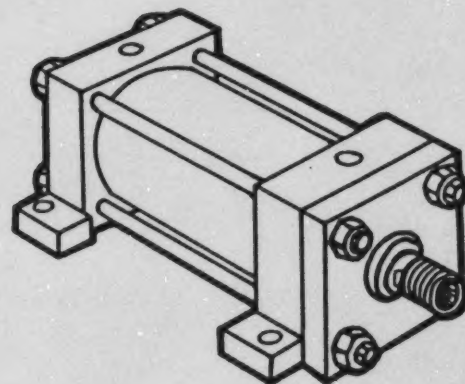
CAP FIXED CLEVIS



CAP TRUNNION

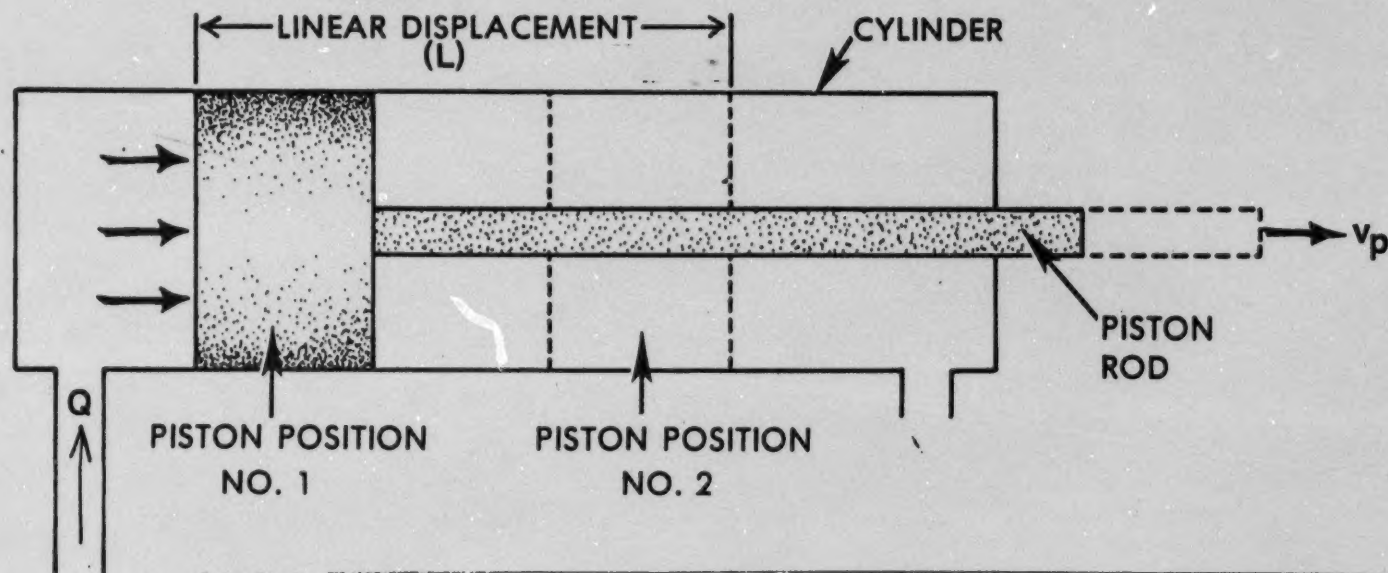


CAP SQUARE FLANGE



SIDE LUG

# LINEAR DISPLACEMENT, VOLUMETRIC DISPLACEMENT, PISTON VELOCITY AND FLOW RATE OF SINGLE-ACTING CYLINDER



$A$  = AREA OF PISTON  
 $L$  = LINEAR DISPLACEMENT  
 $V$  = VOLUMETRIC DISPLACEMENT  
 $t$  = PISTON TRAVEL TIME  
 $v_p$  = PISTON VELOCITY  
 $Q$  = FLOW RATE

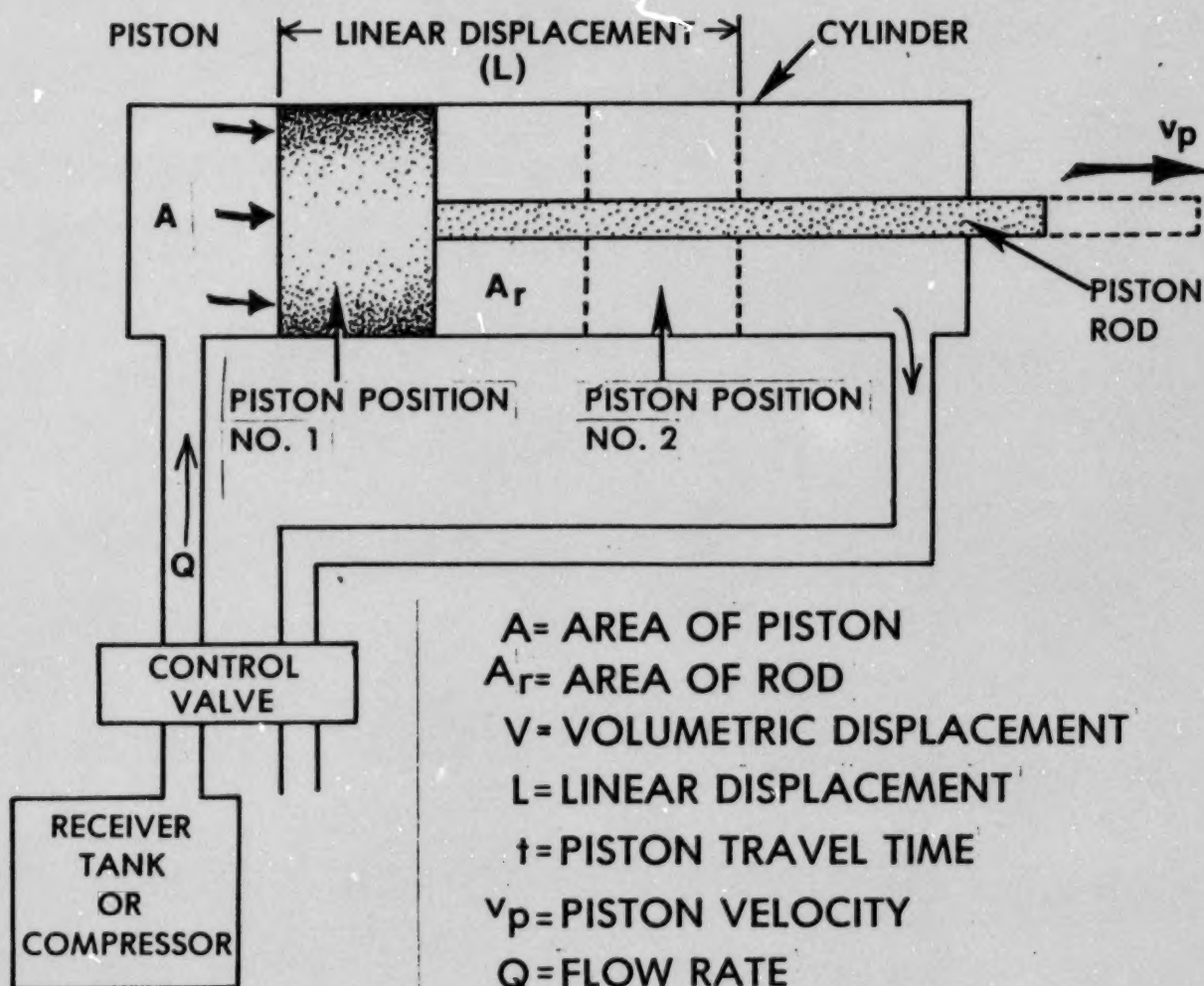
$$V = AL$$

$$v_p = \frac{L}{t}$$

$$Q = \frac{V}{t} = \frac{AL}{t} = Av_p$$



# LINEAR DISPLACEMENT, VOLUMETRIC TM-5 DISPLACEMENT, PISTON VELOCITY AND FLOW RATE OF DOUBLE-ACTING SINGLE ROD CYLINDER



PISTON EXTENDING

$$V = AL$$

$$v_p = \frac{L}{t}$$

$$Q = \frac{V}{t} = \frac{AL}{t} = A v_p$$

PISTON RETRACTING

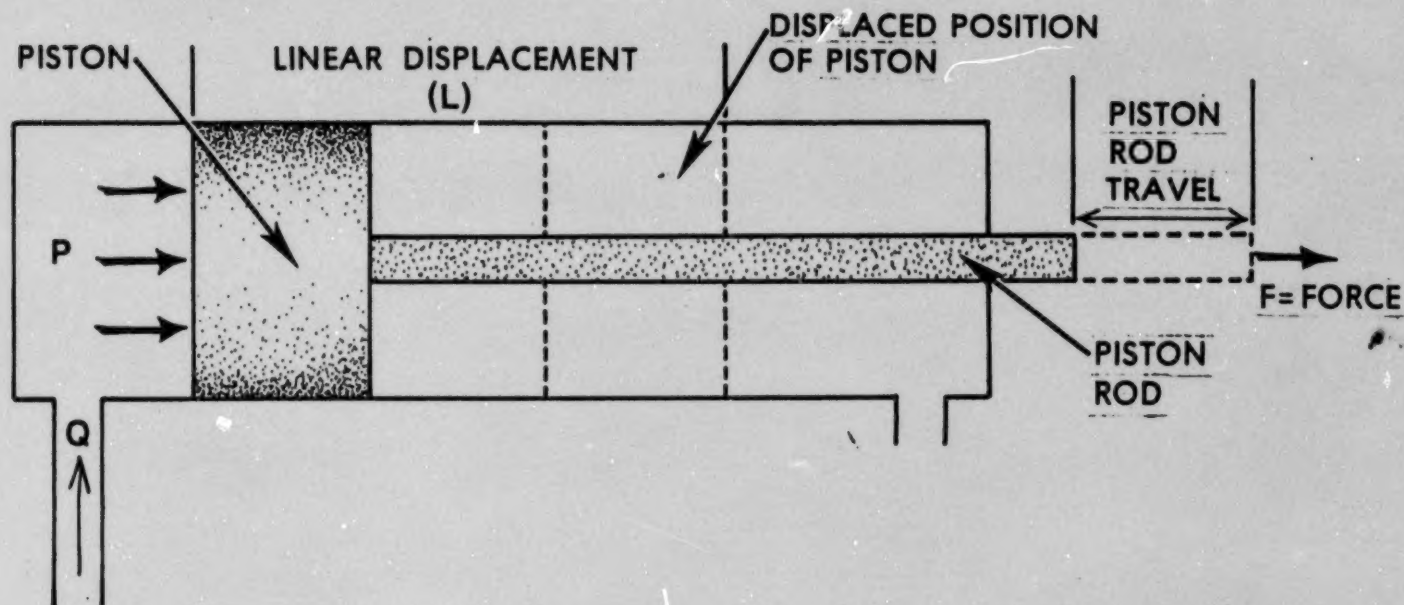
$$V = (A - A_r) L$$

$$v_p = \frac{L}{t}$$

$$Q = \frac{V}{t} = \frac{(A - A_r) L}{t} = (A - A_r) v_p$$



# FORCE, WORK AND POWER OUTLET OF SINGLE-ACTING CYLINDER



A = AREA OF PISTON

L = LINEAR DISPLACEMENT

t = PISTON TRAVEL TIME

$v_p$  = PISTON VELOCITY

P = PRESSURE ACTING ON THE PISTON

F = FORCE ACTING ON THE PISTON

W = WORK

POWER = CYLINDER HORSEPOWER

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$$F = PA$$

$$W = FL = PAL$$

$$\text{POWER} = \frac{W}{t} = \frac{FL}{t} = Fv_p$$

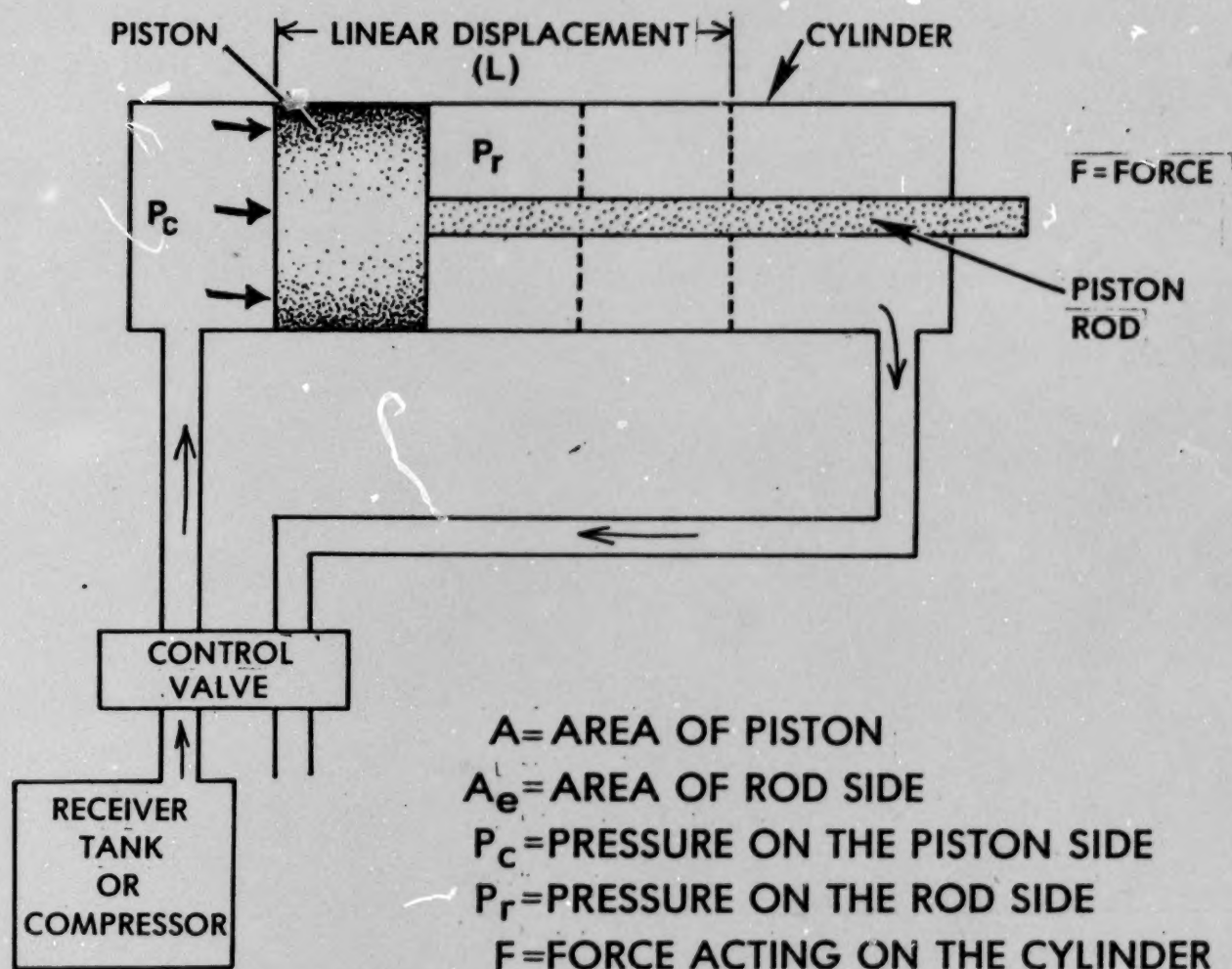
$$\text{HORSEPOWER} = \frac{Fv_p}{33.000} \text{ (when 't' is in minutes)}$$

$$\text{HORSEPOWER} = \frac{Fv_p}{550} \text{ (when 't' is in seconds)}$$

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9-11

# FORCE ACTING ON DOUBLE-ACTING CYLINDER



PISTON EXTENDING

$$F = AP_c - A_e P_r$$

PISTON RETRACTING

$$F = A_e P_r - AP_c$$

LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT V : ACTUATORS

SCOPE OF UNIT:

After the completion of this unit, the student will be familiar with pneumatic actuators, which are devices that convert fluid power (air) into linear and rotational mechanical motion or force.

INFORMATION TOPIC: V-2

PRESSURE BOOSTERS  
(Lesson Title)

LESSON OBJECTIVES - THE STUDENT SHOULD BE ABLE TO:

1. Define a pressure booster.
2. Name and describe the types of pressure boosters.
3. Identify a double pressure application and single intensification booster and list its parts.
4. List the advantages of pressure boosters.
5. List some applications of pressure boosters.
6. Given the necessary data, calculate the pressure intensified by boosters.
7. Draw the symbols for double pressure application, single and double intensification boosters.

SUPPLEMENTARY TEACHING/LEARNING ITEMS:

1. TM 1: Types of Pressure Boosters
  - A. Single Pressure Application and Single Intensification
  - B. Double Pressure Application and Single Intensification
2. TM 2: Double Pressure Application and Double Intensification
3. TM 3: Basic Parts of a Double Pressure Application and Single Intensification Booster
4. TM 4: Pressure Intensification Formula

INFORMATIONAL ASSIGNMENT: (Student)

IML Fluid Power/Basic Hydraulics, Lesson II-16 (Components)

Stewart, L. Harry. Pneumatics and Hydraulics. 3rd ed. Indianapolis, IN: Theodore Audel and Co., 1978.

Industrial Pneumatic Technology, Bulletin 0275-B1. Parker Hannifin Corporation, 1980.

REFERENCES: (Instructor's Additional Information)

IML Fluid Power/Basic Hydraulics, Lesson II-16 (Components)

Stewart, L. Harry. Pneumatics and Hydraulics. 3rd ed. Indianapolis, IN: Theodore Audel and Co., 1978.

Industrial Pneumatic Technology, Bulletin 0275-B1. Parker Hannifin Corporation, 1980.

INTRODUCTION:

In situations when the use of compressors to supply a desired operating pressure is neither technically nor economically feasible, pressure boosters can be used to increase or decrease the air pressure to a desired level.



LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT V : ACTUATORS

INFORMATION TOPIC: V-2

OUTLINE: (Key Points)

- I. Pressure booster - a device which increases fluid pressure
- II. Types of pressure boosters
  - A. Single pressure application and single intensification is a booster where pressure is applied in one direction and is intensified in the other (TM 1A).

Piston retracting methods

    1. Spring return
    2. Gravity return
  - B. Double pressure application and single intensification is a booster where pressure is applied in both directions and intensified in one direction only (TM 1B).

Piston retracting method: Piston returns to its starting position when air flow is directed to enter the cylinder from the ram end side.
  - C. Double pressure application and double intensification is a booster where pressure is applied and intensified in two directions (TM 2).

Piston retracting method: Piston returns when air flow is directed to enter the cylinder from the opposite side of the booster.
- III. Basic parts of double pressure application and single intensification booster (TM 3)
  - A. Inlet port
  - B. Piston
  - C. Driving cylinder
  - D. Piston seals
  - E. Tie rod
  - F. Ram
  - G. Ram packing

H. Booster chamber

I. Outlet port

IV. Advantages of pressure boosters

- A. Less expensive than high pressure output compressors
- B. A much higher pressure can be obtained than can be obtained by a practical compressor.
- C. Heat production in the system can be reduced.
- D. Air-operated boosters can be operated near explosive atmosphere.
- E. Pressure boosters can provide both high and low pressure for a single compressor unit.
- F. Low pressure components such as valves can be used in the system.

V. Some applications of pressure boosters

- A. Pneumatic presses
- B. Drills
- C. Pavement breakers
- D. Rivet driving machines
- E. Molding machines
- F. Clamping devices

VI. Pressure intensification formulas and procedures (TM 4)

- A. Determine the available operating pressure  $P$  from the supply compressor or receiver tank which is acting on the piston.
- B. Calculate the force  $F$  acting on the piston.  $F = \text{Pressure } P \times \text{Area } A \text{ of Piston}$   
$$F = PA$$
- C. The force imparted to and transmitted from the ram is equal to  $F$ .
- D. The pressure intensified  $P_i$  is equal to the force  $F$  divided by the booster chamber area  $A_c$ .

$$P_i = \frac{F}{A_c}$$

$$\text{or } P_i = \frac{PA}{A_c} = KP$$

Where  $K$  (intensifier ratio) =  $\frac{A}{A_c} = \frac{D^2}{d^2}$  and  $D$  and  $d$  are diameters of the piston and booster chamber, respectively.

(NOTE: Normally the diameter of the ram and booster chamber are equal.)

Example: If a pneumatic pressure booster cylinder is 6 inches in diameter and is operated by 150 psi pressure, calculate the intensified pressure if the booster chamber and ram are 1 inch in diameter.

Pressure acting on the piston =  $P = 150$  psi

Area of piston =  $A = \frac{\pi D^2}{4} = \frac{3.14(6)^2}{4} = 28.26$  sq.in.

Force acting on the piston =  $F = PA = 150$  lbs./sq.in.  $\times$  28.26 sq.in. = 4239 lbs.

Area of booster chamber =  $A_c = \frac{\pi (1)^2}{4} = 0.785$  sq.in.

Intensified pressure =  $P_i = \frac{F}{A_c} = \frac{4239 \text{ lbs.}}{0.785 \text{ sq.in.}} = 5400$  psi

Alternative solution:

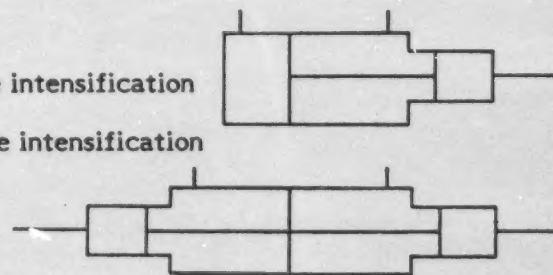
Intensifier ratio =  $K = \frac{A}{A_c} = \frac{D^2}{d^2} = (6)^2 = 36$

Intensified pressure =  $P_i = KP = 36 \times 150$  lbs./sq.in. = 5400 lbs.

## VII. Symbols

A. Double pressure application and single intensification

B. Double pressure application and double intensification



LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT V : ACTUATORS

INFORMATION TOPIC: V-2

INTERACTION ITEMS:

1. How is it possible for a pressure booster to provide both high and low pressure for a single compressor unit?

CLASSROOM, LABORATORY, SHOP, OR OTHER ACTIVITIES:



LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT V : ACTUATORS

INFORMATION TOPIC: V-2

EVALUATION ITEMS:

1. Define a pressure booster.
2. Name and describe the types of pressure boosters.
3. Identify the type of booster shown below and write the names of the parts in the space next to the appropriate letter.

a.

b.

c.

d.

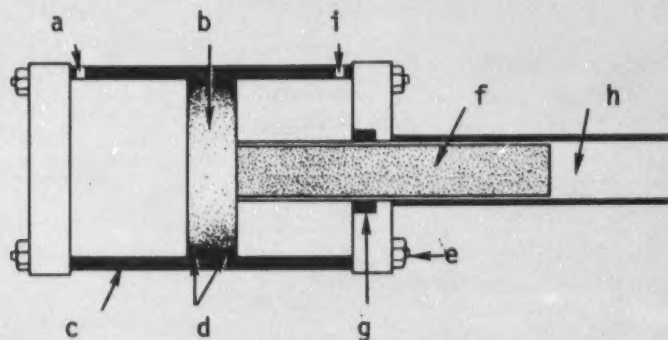
e.

f.

g.

h.

i.



4. List at least four advantages of pressure boosters.

a.

b.

c.

d.

5. List at least four applications of pressure boosters.

a.

b.

c.

d.

6.1. Calculate the intensified pressure, if the driving cylinder is 4 inches in diameter, booster chamber is 1 inch in diameter and the booster is operated by a pressure of 200 psi.

6.2. Complete the missing data for the table shown below.

| Booster Chamber  |                   | Driving Cylinder |                   | Intensifier<br>Ratio<br>K | Intensified Pressure for<br>Operating Pressure of |              |
|------------------|-------------------|------------------|-------------------|---------------------------|---------------------------------------------------|--------------|
| Diameter<br>(in) | Area<br>(sq. in.) | Diameter<br>(in) | Area<br>(sq. in.) |                           | 100<br>(PSI)                                      | 200<br>(PSI) |
| 4                |                   | 1                |                   | 9<br>64                   | 900<br>6400                                       |              |
| 8                |                   | 2                |                   |                           |                                                   |              |
| 10               |                   | 2                |                   |                           |                                                   |              |
| 12               |                   | 2                |                   |                           |                                                   |              |

7. Draw these symbols.

a. Double pressure application and single intensification booster.

b. Double pressure application and double intensification booster.

LESSON PLAN: 2

COURSE TITLE: BASIC PNEUMATICS

UNIT V : ACTUATORS

INFORMATION TOPIC: V-2

ANSWERS TO EVALUATION ITEMS:

1. A pressure booster is a device which increases fluid pressure.
2.
  - a. Single pressure application and single intensification is a booster where pressure is applied in one direction and is intensified in the other (TM 1A)  
Piston retracting methods
    1. Spring return
    2. Gravity return
  - b. Double pressure application and single intensification is a booster where pressure is applied in both directions and intensified in one direction only.  
Piston retracting method: Piston returns to its starting position when air flow is directed to enter the cylinder from the ram end side.
  - c. Double pressure application and double intensification is a booster where pressure is applied and intensified in two directions.  
Piston retracting method: Piston returns when air flow is directed to enter the cylinder from the opposite side of the booster.
3. Type of booster: Double pressure application and single intensification
  - a. Inlet port
  - b. Piston
  - c. Driving cylinder
  - d. Piston seals
  - e. Tie rod
  - f. Ram
  - g. Ram packing
  - h. Booster chamber
  - i. Outlet port
4. The list should include:
  - a. Less expensive than high pressure output compressors
  - b. A much higher pressure can be obtained than can be obtained by a practical compressor.
  - c. Heat production in the system can be reduced.
  - d. Air-operated boosters can be operated near explosive atmosphere.
  - e. Pressure boosters can provide both high and low pressure for a single compressor unit.
  - f. Low pressure components such as valves can be used in the system.
5. The list should include
  - a. Pneumatic presses
  - b. Drills
  - c. Pavement breakers
  - d. Rivet driving machines

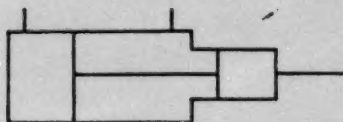
- e. Molding machines
- f. Clamping devices

6.1. Intensified pressure = 3200 psi.

6.2.

| Booster Chamber  |                   | Driving Cylinder |                   | Intensifier Ratio<br>K | Intensified Pressure for<br>Operating Pressure of |              |
|------------------|-------------------|------------------|-------------------|------------------------|---------------------------------------------------|--------------|
| Diameter<br>(in) | Area<br>(sq. in.) | Diameter<br>(in) | Area<br>(sq. in.) |                        | 100<br>(PSI)                                      | 200<br>(PSI) |
| 4                | 12.57             | 1                | 0.785             | 16                     | 1600                                              | 3200         |
| 6                | 28.27             | 2                | 3.142             | 9                      | 900                                               | 1800         |
| 8                | 50.26             | 1                | 0.785             | 64                     | 6400                                              | 12800        |
| 10               | 78.54             | 2                | 3.142             | 25                     | 2500                                              | 5000         |
| 12               | 111.10            | 2                | 3.142             | 36                     | 3600                                              | 7200         |

7. a.

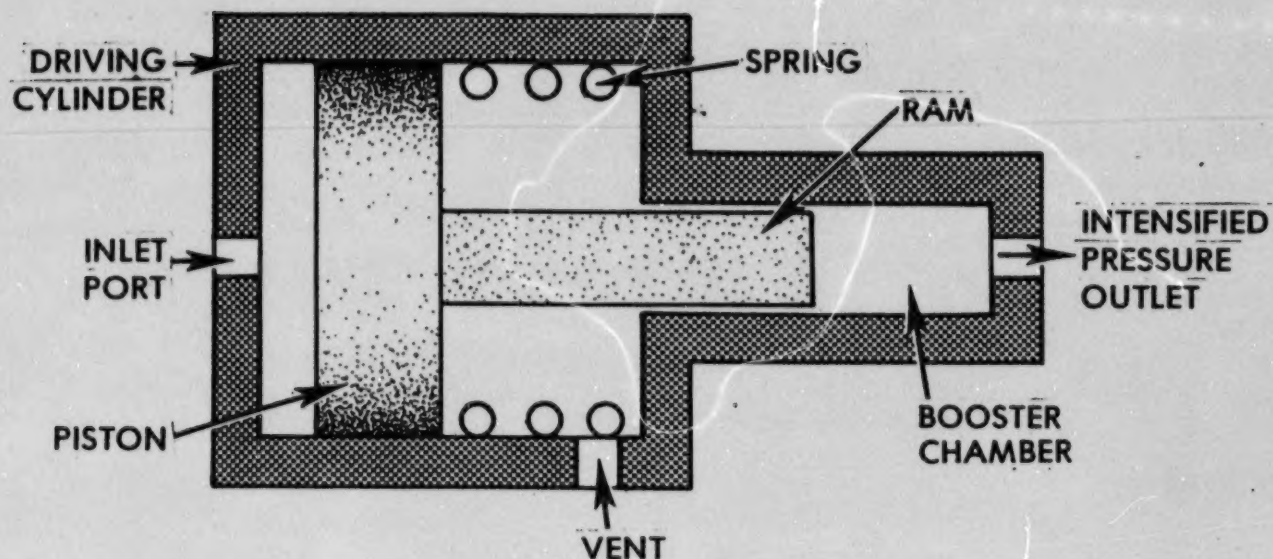


b.



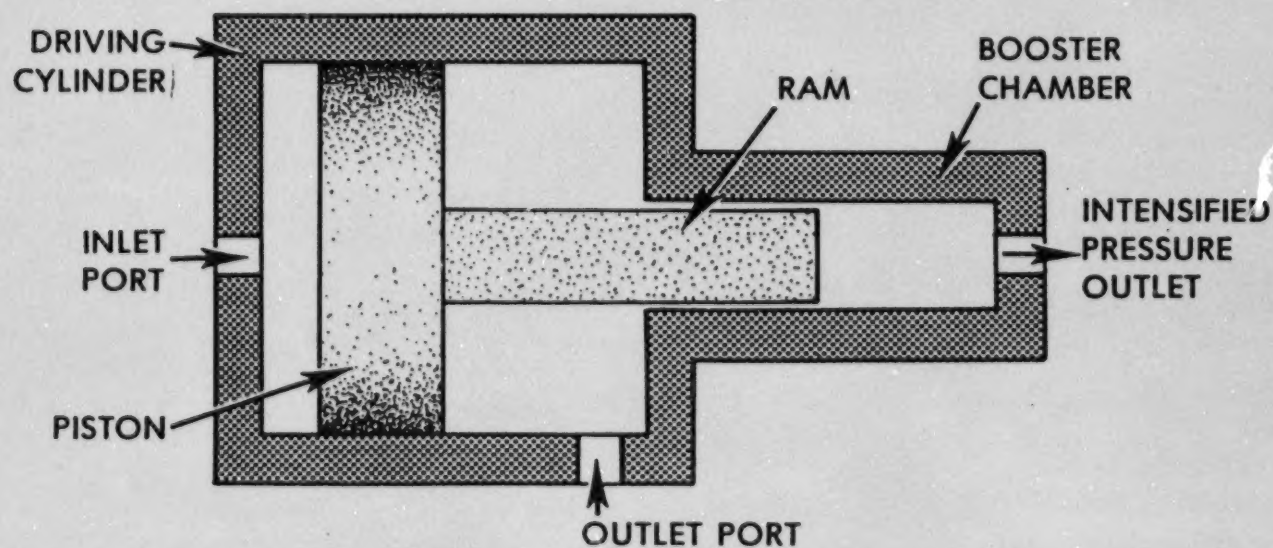


# TYPES OF PRESSURE BOOSTERS <sup>TM-1</sup>



## SINGLE PRESSURE APPLICATION AND SINGLE INTENSIFICATION

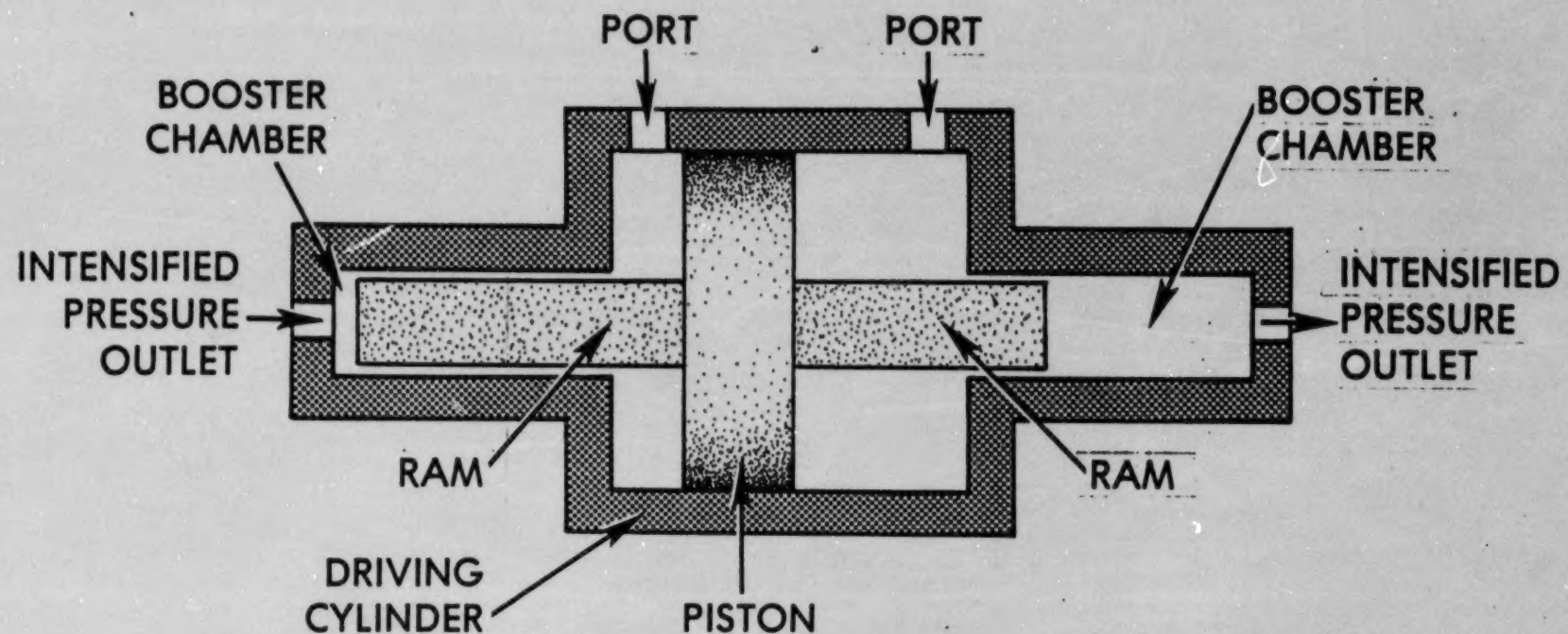
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## DOUBLE PRESSURE APPLICATION AND SINGLE INTENSIFICATION

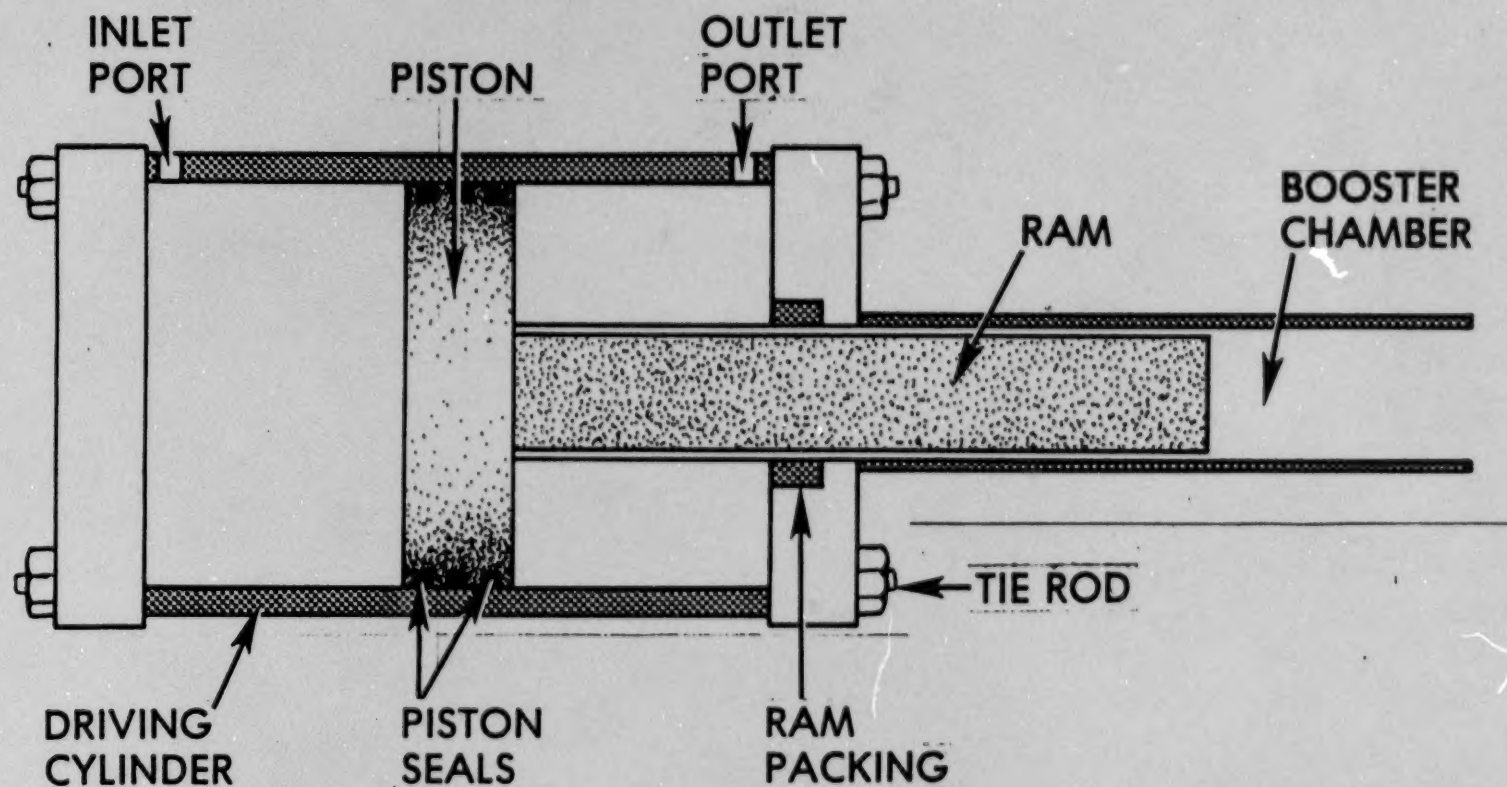
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# PRESSURE BOOSTER



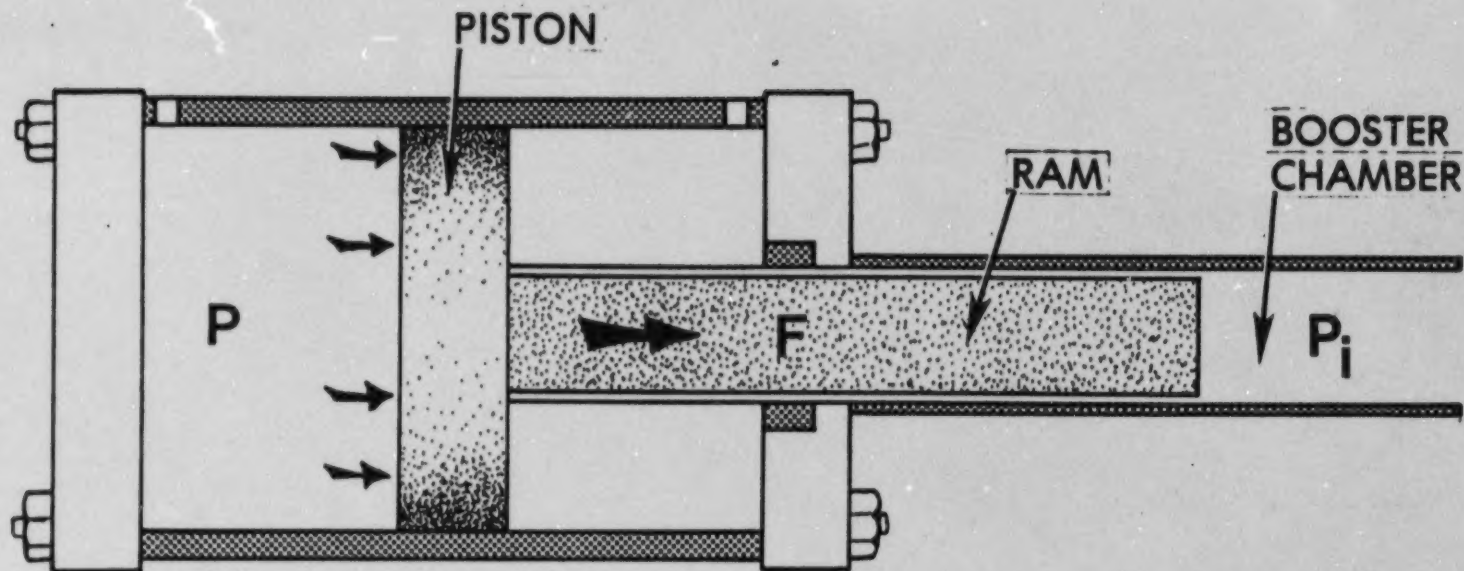
DOUBLE PRESSURE APPLICATION AND DOUBLE INTENSIFICATION

## BASIC PARTS OF DOUBLE APPLICATION AND SINGLE INTENSIFICATION BOOSTER





# PRESSURE INTENSIFICATION FORMULA



P = OPERATING PRESSURE

A = AREA OF PISTON

$A_c$  = BOOSTER CHAMBER AREA

F = FORCE ACTING ON PISTON = FORCE  
IMPARTED FROM RAM

$P_i$  = INTENSIFIED PRESSURE

$K$  = INTENSIFIER RATIO =  $A/A_c$

230

$$P_i = \frac{F}{A_c} = \frac{PA}{A_c} = KP$$

231



LESSON PLAN: 3

COURSE TITLE: BASIC PNEUMATICS

UNIT V : ACTUATORS

SCOPE OF UNIT:

After the completion of this unit, the student will be familiar with pneumatic actuators, which are devices that convert fluid power (air) into linear and rotational mechanical motion or force.

INFORMATION TOPIC: V-3

PNEUMATIC MOTORS  
(Lesson Title)

LESSON OBJECTIVES - THE STUDENT SHOULD BE ABLE TO:

1. Match terms related to pneumatic motors with the correct definition.
2. Compare compressors and pneumatic motors.
3. Name the types of pneumatic compressors.
4. Identify the components and discuss the operating principles of vane motors.
5. Identify the components and discuss the operating principles of gear motors.
6. Identify the components and discuss the operating principles of reciprocating axial piston motors.
7. Name four typical applications of pneumatic motors and give one example of each.
8. Define torque, and given a force and its perpendicular distance, determine torque of a motor.
9. Given the torque and speed of a motor, determine the output power of that motor.
10. Determine the overall efficiency of a motor.
11. Draw the symbols for the types of motors.

SUPPLEMENTARY TEACHING/LEARNING ITEMS:

1. TM 1: Sliding Vane Rotary Motor
2. TM 2: Gear Rotary Motor
3. TM 3: Reciprocating Axial Piston Motor
4. TM 4: Relationship between Torque and Force

**INFORMATIONAL ASSIGNMENT: (Student)**

**IML Fluid Power/Basic Hydraulics, Lesson II-16 (Components)**

Stewart, L. Harry. Pneumatics and Hydraulics. 3rd ed. Indianapolis, IN: Theodore Audel and Co., 1978.

Industrial Pneumatic Technology, Bulletin 0275-B1. Parker Hannifin Corporation, 1980.

**REFERENCES: (Instructor's Additional Information)**

Fluid Power/Basic Hydraulics Lesson II-16 (Components). Instructional Materials Laboratory. Columbia, MO: University of Missouri-Columbia.

Stewart, L. Harry. Pneumatics and Hydraulics. 3rd ed. Indianapolis, IN: Theodore Audel and Co., 1978.

Industrial Pneumatic Technology, Bulletin 0275-B1. Parker Hannifin Corporation, 1980.

**INTRODUCTION:**

It is often difficult to distinguish between air compressors and pneumatic motors. The difference between the two is that compressors, driven by other motors, compress the air for immediate or future use, while pneumatic motors use the energy of compressed air to drive other machines.

LESSON PLAN: 3

COURSE TITLE: BASIC PNEUMATICS

UNIT V : ACTUATORS

INFORMATION TOPIC: V-3

OUTLINE: (Key Points)

I. Terms and definitions

- A. **Pneumatic motor** - a device converting the energy of compressed air into mechanical force and motion
- B. **Torque** - a measure of rotational (twisting) load or effort; calculated as force times distance
- C. **Displacement** - the volume of air which is transported from the motor inlet to the outlet during one revolution or stroke of a motor
- D. **Fixed displacement motor** - a motor in which the displacement per revolution cannot be varied
- E. **Variable displacement motor** - a motor in which the displacement per revolution can be varied
- F. **Efficiency** - the output power divided by the input power
- G. **Foot-pound** - a unit of torque equal to 12 inch-pounds

(NOTE: Foot-pounds are abbreviated ft-lbs.)

II. Comparison between compressors and pneumatic motors

A. In compressors:

- 1. The energy of a mechanical or electrical motor is converted to potential energy of compressed air.
- 2. The drive shaft drives the compressor rotor.
- 3. The air pressure on the inlet of the compressor is less than the outlet pressure.

B. In pneumatic motors:

- 1. The potential energy of compressed air is converted to mechanical energy.
- 2. The motor rotor drives the drive shaft.



3. The air pressure on the inlet of the motor is greater than the pressure on the outlet.

### III. Types of pneumatic motors

#### A. Rotary

1. Vane
2. Gear

#### B. Reciprocating piston

1. Axial
2. Radial

### IV. Vane motors (TM 1)

#### A. Components

1. Inlet port
2. Outlet port
3. Casing or housing
4. Rotor (positioned off-center of casing and slotted)
5. Sliding vanes
6. Shaft (driven)

#### B. Assembly of components and operation

1. The rotor is installed off-center in the housing.
2. The vanes are installed in the rotor and are free to move radially.
3. The vanes are spring-loaded to force the vanes to contact the surface of the housing.
4. Pressurized air is supplied to the inlet of the motor.
5. Because the rotor is installed off-center, an imbalance of forces on the vanes is created which tends to cause the rotor and the motor shaft to turn.
6. As the rotor turns, a small volume of air is trapped and carried to the outlet and expelled at a lower pressure.



(NOTE: Some vane motors are designed to balance the load on the shaft bearing by having two inlet and two outlet ports. The inlet ports are positioned directly opposite each other. This design is called a balanced vane motor.)

#### V. Gear motors (TM 2)

##### A. Components

1. Inlet port
2. Outlet port
3. Housing
4. Gears
5. Shaft (driven)

##### B. Operation

1. Pressurized air is supplied to the inlet of the motor.
2. The pressure creates a force on the face of each gear tooth.
3. Balancing of forces exists at all gear teeth except where the teeth just begin to disengage.
4. The forces which are not balanced tend to cause the motor to rotate.
5. As the motor rotates, small volumes of air are trapped between the gear teeth and are carried to the outlet.
6. The air at the outlet is expelled at a lower pressure.

#### VI. Reciprocating axial piston motors (TM 3)

##### A. Components

1. Inlet port
2. Outlet port
3. Valve plate
4. Pistons (odd number of pistons, i.e., 3, 5, 7, etc.)
5. Cylinder barrel
6. Housing
7. Cam plate
8. Piston shoes

9. Shaft (driven)

B. Operation

1. Compressed air from a compressor or receiver tank enters the inlet port.
2. Air passes the valve plate pushing against the piston and piston shoes assembly, causing it to seek the lower side of the sloping face of the cam plate.

(NOTE: The opening of the valve plate connected to the power stroke is in line with the piston or pistons which are in the power stroke.)

3. Since the cam plate is fixed, the piston barrel and shaft move or rotate due to the tangential force acting on the point of contact of the piston shoes and sloping cam plate.
4. As the piston and piston-shoes assembly reaches the other half of the revolution, the cam plate pushes the pistons back into the cylinder, exhausting air through the outlet port. Note that the opening of the valve plate connected to the exhaust stroke is in line with the piston or pistons retracting.

VII. Typical applications of pneumatic motors

A. Abrasive tools

1. Grinders
2. Sanders

B. Drilling tools

1. Drills
2. Reamers
3. Tappers

C. Screw drivers

1. Nut setters
2. Impact wrenches

D. Hammers

1. Chipping hammers
2. Forming tools
3. Chisels

#### 4. Pavement breakers

##### E. Hoists

### VIII. Determination of torque

- A. Given a force (F) and its perpendicular distance from the center of the shaft, (TM 4)

Torque = Force x Perpendicular distance

$$T = F \times r$$

Where     T = Torque in ft-pounds or inch-pounds  
            F = Force acting on the shaft in pounds  
            r = Perpendicular distance from the center of the shaft to the line of action of the force in units of feet or inches.

Example: If a 100-pound force is applied to the shaft of a motor one foot from the center of the shaft, then the output torque is 100 ft-pounds.

Torque = Distance x Force

$$\text{Torque} = (1 \text{ ft})(100 \text{ pounds}) = 100 \text{ ft-pounds}$$

- B. Given the available pressure, motor displacement, and motor efficiency

$$\text{Torque} = \frac{\text{Pressure (gage)} \times \text{Displacement} \times \text{Efficiency}}{2\pi}$$

$$T = \frac{P \times V_r \times \text{Eff.}}{2\pi}$$

Where     T = Output torque in inch-pounds  
            P = Available gage pressure, psig  
             $V_r$  = Motor displacement in cubic inches  
            Eff. = Motor efficiency  
             $\pi = 3.14$

Example: A 70% efficient motor is driven by 100 psig pressure. If the displacement of the motor is 62 cubic inches, determine the output torque

$$T = \frac{P \times V_r \times \text{Eff.}}{2\pi}$$

$$T = \frac{(100 \text{ lbs./sq.in.}) \times (62 \text{ cu.in.}) \times 0.70}{2 \times 3.14} = 691.1 \text{ in-pounds} = 57.6 \text{ ft-pounds}$$

### IX. Relation between torque and power (horsepower)

$$\text{Power (horsepower)} = \frac{\text{Torque} \times \text{rpm}}{5252} = \frac{Tn}{5252}$$

Power = Output power in units of horsepower (hp)  
n = Shaft speed in revolutions per minute (rpm)



T = Torque in units of foot-pounds (ft-lbs.)

Example: The output power of a motor operated at 2400 rpm with an output of 70 ft-lbs. is 32 hp.

$$\text{Power} = \frac{(2400 \text{ rpm})(70 \text{ ft-lbs.})}{5252} = 32 \text{ hp}$$

X. Formula for the calculation of motor overall efficiency:

$$\text{Eff} = \frac{\text{Output power}}{\text{Input power}}$$

Example: A motor is operated at the output power of 24 hp. The input power required is 32 hp. The efficiency is 0.844.

$$\text{Eff} = \frac{27}{32} = 0.844; \text{ therefore the motor is } 84.4\% \text{ efficient.}$$

XI. Symbols

A. Fixed displacement motor



B. Variable displacement motor





LESSON PLAN: 3

COURSE TITLE: BASIC PNEUMATICS

UNIT V : ACTUATORS

INFORMATION TOPIC: V-3

INTERACTION ITEMS: (Review Items)

1. Is it possible for a rotary vane compressor to be used as a pneumatic motor? If yes, how?
2. Discuss why the air is at a lower pressure when it leaves than when it enters the motor.
3. In all motors, including pneumatic motors, the efficiency is less than 100%. Why?

CLASSROOM, LABORATORY, SHOP, OR OTHER ACTIVITIES:

LESSON PLAN: 3

COURSE TITLE: BASIC PNEUMATICS

UNIT V : ACTUATORS

INFORMATION TOPIC: V-3

EVALUATION ITEMS:

1. Match the terms on the right with the correct definition

- |        |                                                                                                 |    |                             |
|--------|-------------------------------------------------------------------------------------------------|----|-----------------------------|
| ___ a. | Device for converting the energy of compressed air into mechanical force and motion             | 1. | Variable displacement motor |
| ___ b. | The volume of air which is transported from the motor inlet to the outlet during one revolution | 2. | Fixed displacement motor    |
| ___ c. | A motor in which the displacement per revolution cannot be varied                               | 3. | Foot-pound                  |
| ___ d. | The output power divided by the input power                                                     | 4. | Efficiency                  |
| ___ e. | A measure of rotational (twisting) load or effort, calculated as force times distance.          | 5. | Displacement                |
| ___ f. | A motor in which the displacement per revolution can be varied                                  | 6. | Torque                      |
| ___ g. | A unit of torque equal to 12 inch-pounds                                                        | 7. | Pneumatic motor             |

2. Compare compressors and pneumatic motors.

3. Name and classify the types of pneumatic motors.

4.1. Identify the type of the pneumatic motor shown below and write the names of the components next to the appropriate letter.

a.

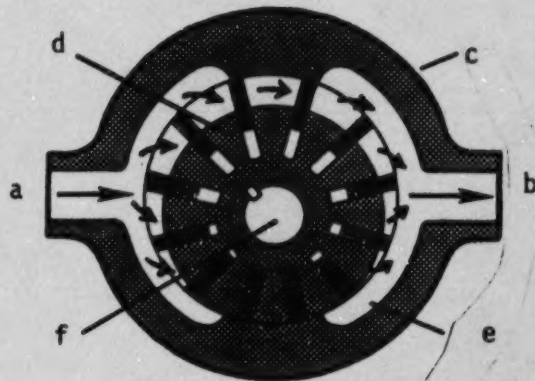
b.

c.

d.

e.

f.



4.2. Discuss the assembly of components and operation of the motor shown above.

5.1. Identify the motor and the components of the motor shown below.

Type of Motor: \_\_\_\_\_

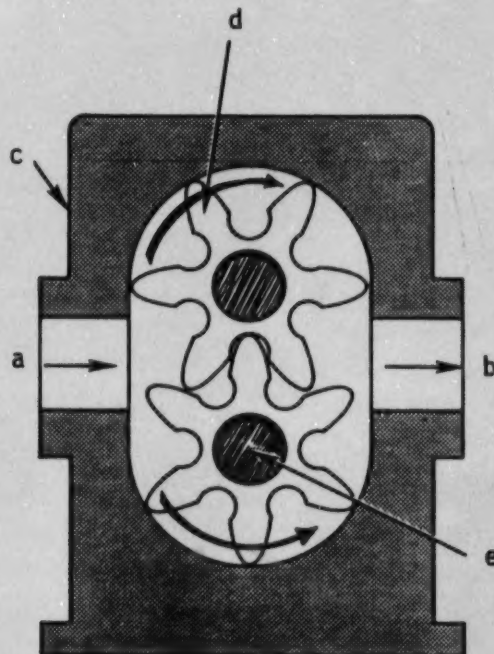
a.

b.

c.

d.

e.





5.2. Discuss the operation of the motor shown above.

6.1. Identify the type of motor and the components of the motor.

Type of Motor: \_\_\_\_\_

a.

b.

c.

d.

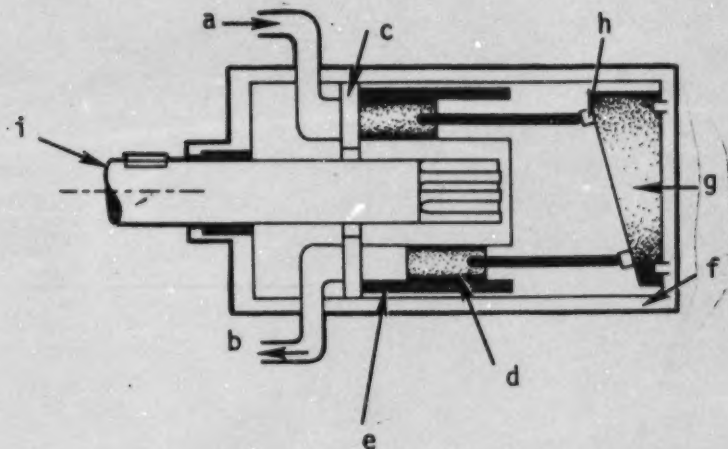
e.

f.

g.

h.

i.



6.2. Discuss the operation of the motor shown above.

7. Name at least four applications of the pneumatic motor and give one example of each.

a.

b.

c.

d.

8.1. Torque = \_\_\_\_\_ x \_\_\_\_\_

8.2. A 200-pound force acts on the shaft of a motor 6 inches from the center of the shaft. Calculate the torque which is acting on the shaft.



- 8.3. A 75% efficient motor is driven by 150 psig pressure. If the displacement of the motor is 70 cubic inches, determine the output torque.
9. The output power of a motor operated at 2000 rpm with an output torque of 54.6 ft-lbs. is \_\_\_\_\_ hp.
10. A motor is operated at an output power of 42 hp. If the input power is 60 hp, determine the efficiency of the motor.
11. Draw the symbols for
- a. Fixed displacement motor
  - b. Variable displacement motor

LESSON PLAN: 3

COURSE TITLE: BASIC PNEUMATICS

UNIT V : ACTUATORS

INFORMATION TOPIC: V-3

ANSWERS TO EVALUATION ITEMS:

1.
  - a. 7
  - b. 5
  - c. 2
  - d. 4
  - e. 6
  - f. 1
  - g. 3
2. Compressors:
  - a. The energy of a mechanical or electrical motor is converted to potential energy of compressed air.
  - b. The drive shaft drives the compressor rotor.
  - c. The air pressure on the inlet of the compressor is less than the outlet pressure.

Pneumatic motors:

  - a. The potential energy of compressed air is converted to mechanical energy
  - b. The motor rotor drives the drive shaft.
  - c. The air pressure on the inlet of the motor is greater than the pressure on the outlet.
3.
  - a. Rotary
    1. Vane
    2. Gear
  - b. Reciprocating piston
    1. Axial
    2. Radial
- 4.1. Type of Motor: Vane Type
  - a. Inlet port
  - b. Outlet port
  - c. Casing or housing
  - d. Rotor (positioned off-center of casing and slotted)
  - e. Sliding vanes
  - f. Shaft (driven)

4.2. Discussion should include

- a. The rotor is installed off-center in the housing.
- b. The vanes are installed in the rotor and are free to move radially.
- c. The vanes are spring-loaded to force the vanes to contact the surface of the housing.
- d. Pressurized air is supplied to the inlet of the motor.
- e. Because the rotor is installed off center, an imbalance of forces on the vanes is created which tends to cause the rotor and the motor shaft to turn.
- f. As the rotor turns, a small volume of air is trapped and carried to the outlet and expelled at a lower pressure.

5.1 Type of Motor: Gear

- a. Inlet port
- b. Outlet port
- c. Housing
- d. Gears
- e. Shaft (driven)

5.2. Discussion should include

- a. Pressurized air is supplied to the inlet of the motor.
- b. The pressure creates a force on the face of each gear tooth.
- c. Balancing of forces exists at all gear teeth except where the teeth just begin to disengage.
- d. The forces which are not balanced tend to cause the motor to rotate.
- e. As the motor rotates, small volumes of air are trapped between the gear teeth and are carried to the outlet.
- f. The air at the outlet is expelled at a lower pressure.

6.1. Type of Motor: Reciprocating axial piston motors

- a. Inlet port
- b. Outlet port
- c. Valve plate
- d. Pistons (odd number of pistons, i.e., 3, 5, 7, etc.)
- e. Cylinder barrel
- f. Housing
- g. Cam plate
- h. Piston shoes
- i. Shaft (driven)

6.2. Discussion should include

- a. Compressed air from a compressor or receiver tank enters the inlet port.
- b. Air passes the valve plate pushing against the piston and piston shoes assembly, causing it to seek the lower side of the sloping face of the cam plate.
- c. Since the cam plate is fixed, the piston barrel and shaft move or rotate due to the tangential force acting on the point of contact of the piston shoes and sloping cam plate.
- d. As the piston and piston shoes assembly reaches the other half of the revolution, the cam plate pushes the pistons back into the cylinder, exhausting air through the outlet port. Note that the opening of the valve plate connected to the exhaust stroke is in line with the piston or pistons retracting.

7. a. Abrasive tools  
1. Grinders  
2. Sanders  
b. Drilling tools  
1. Drills  
2. Reamers  
3. Tappers  
c. Screw drivers  
1. Nut setters  
2. Impact wrenches  
d. Hammers  
1. Chipping hammers  
2. Forming tools  
3. Chisels  
4. Pavement breakers  
e. Hoists

8.1.  $\text{Torque} = \text{Force} \times \text{Perpendicular distance}$

8.2.  $\text{Torque} = 100 \text{ ft-lbs.}$

8.3.  $\text{Output torque} = 1254 \text{ in-lbs} = 104.5 \text{ ft-lbs.}$

9. 21.9 hp

10.  $\text{Eff.} = 70\%$

11. a. Fixed displacement motor

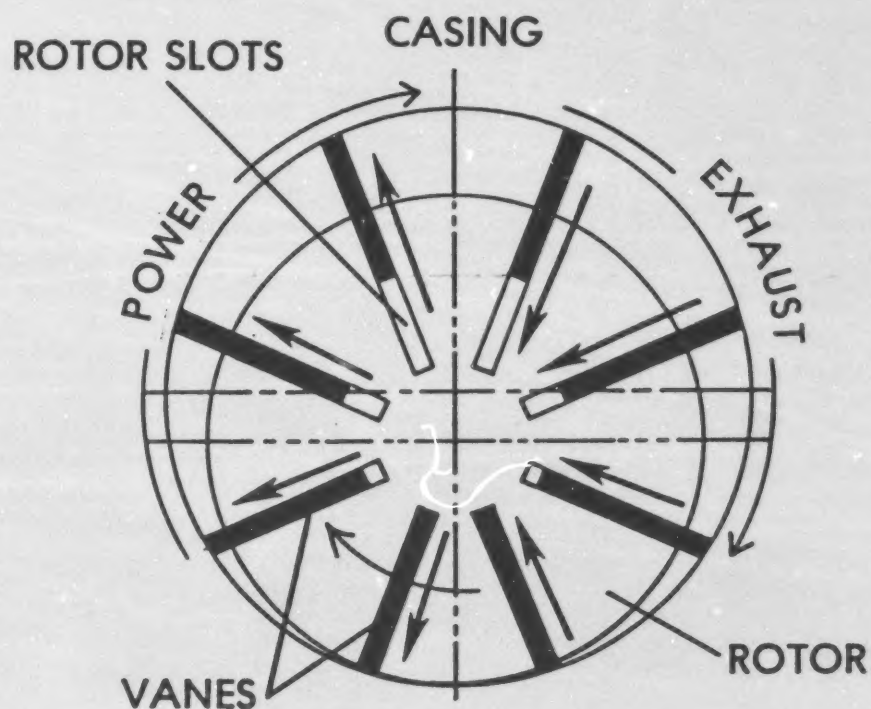
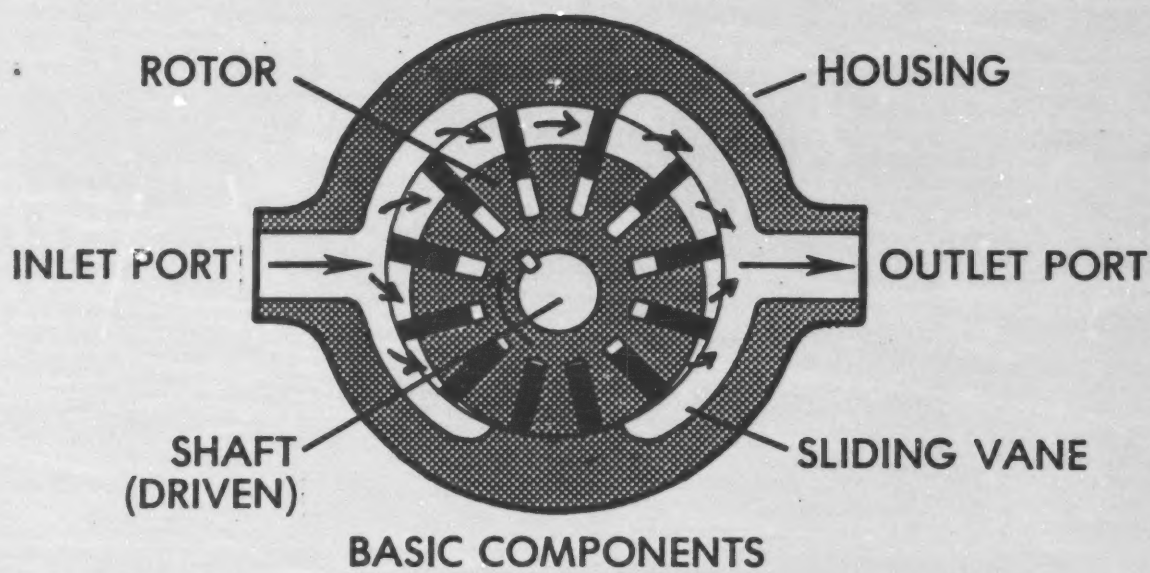


- b. Variable displacement motor

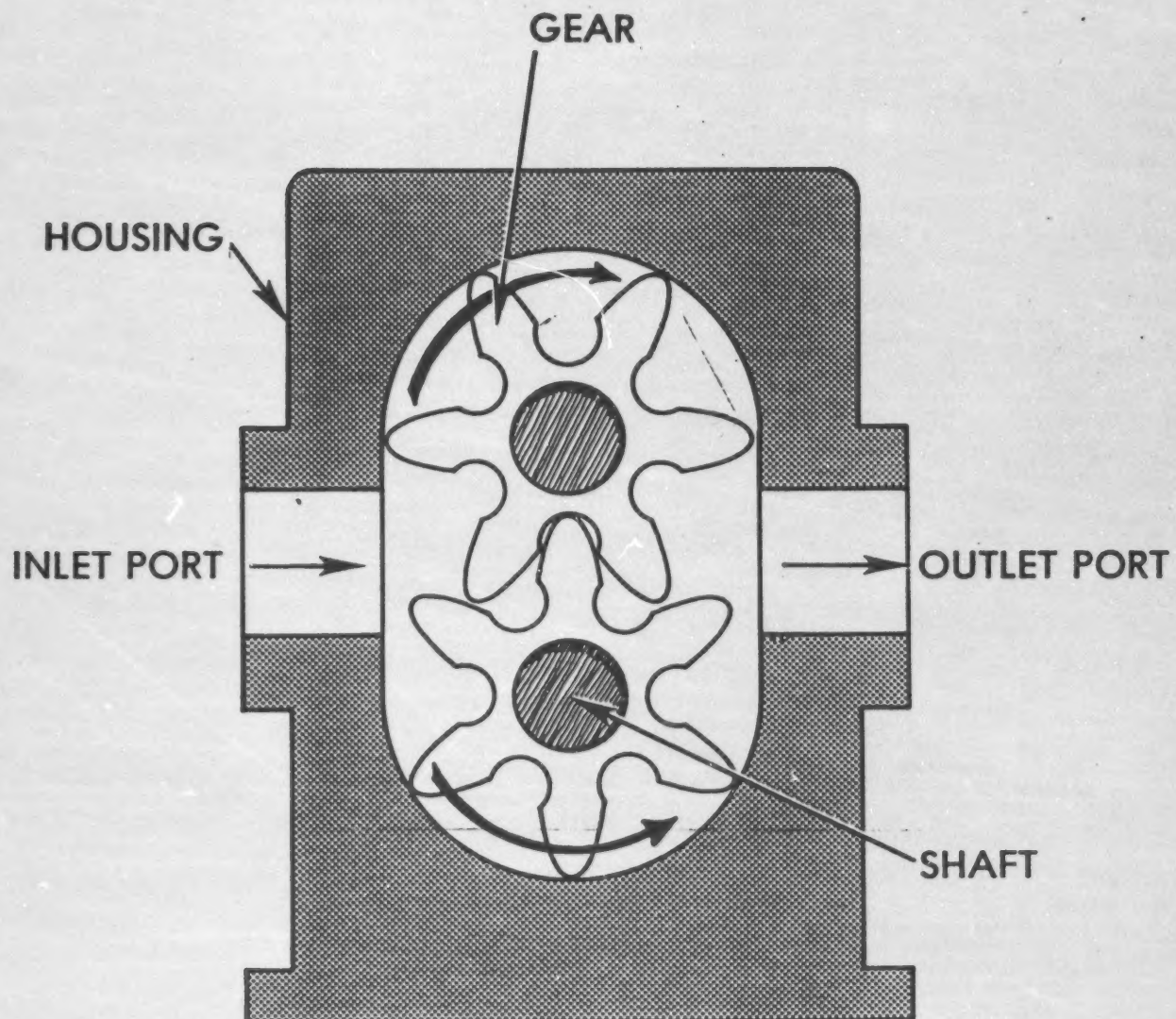




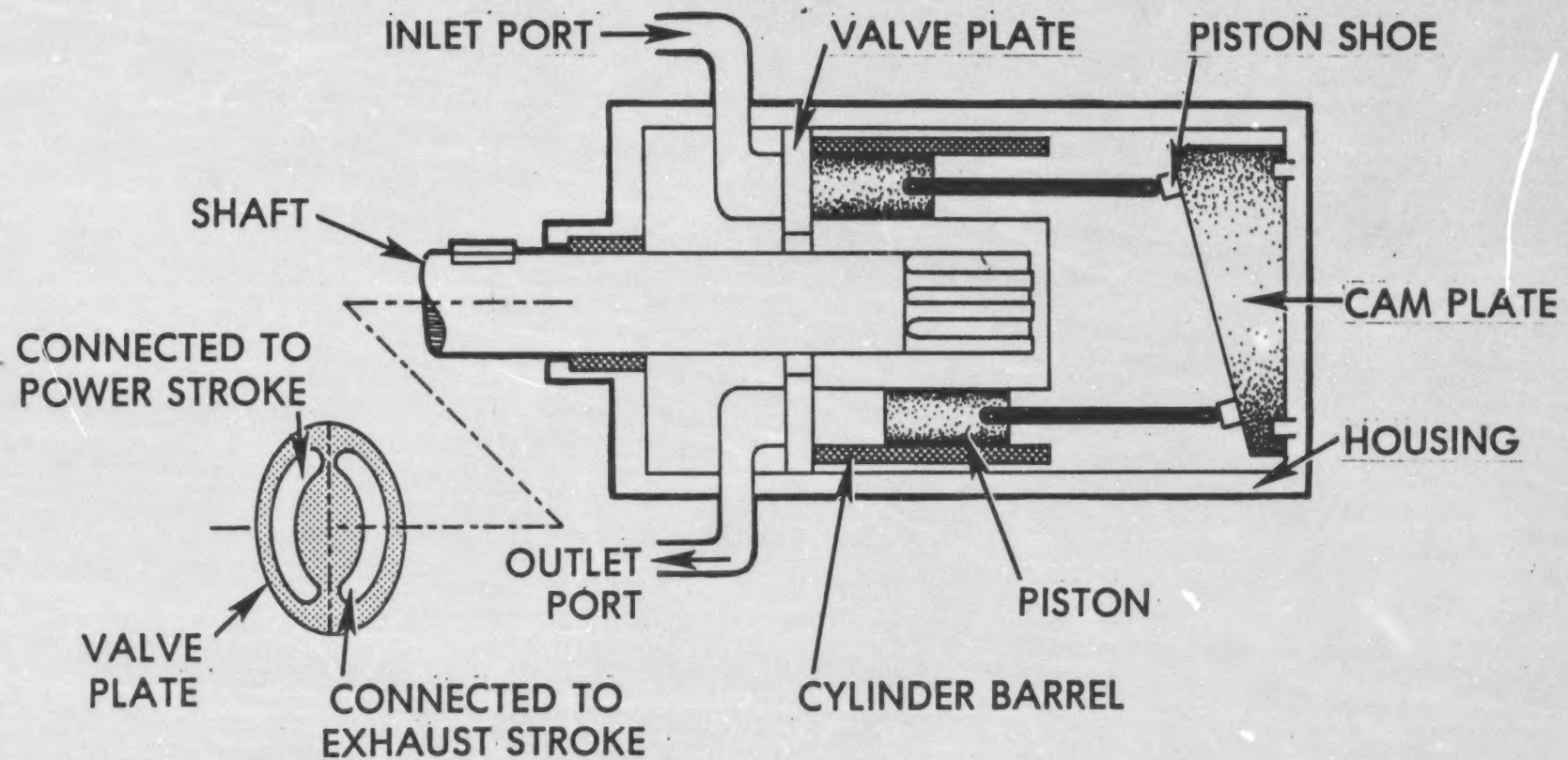
# SLIDING VANE ROTARY MOTOR<sup>TM-1</sup>



# GEAR ROTARY MOTOR



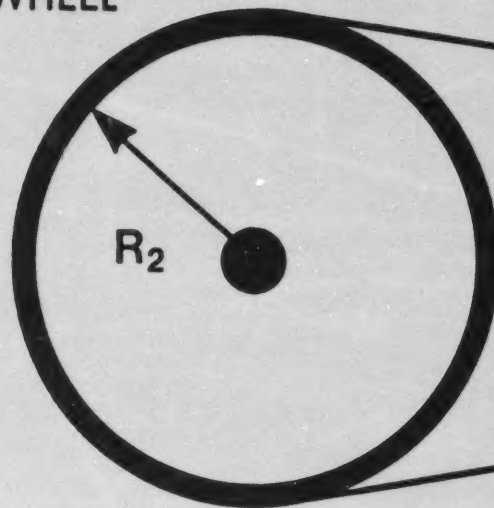
# RECIPROCATING AXIAL PISTON MOTOR





# RELATIONSHIP BETWEEN TORQUE AND FORCE

DRIVEN WHEEL



PULLING FORCE,  $F$

DRIVING WHEEL  
OR MOTOR



NOTE

$T_1$  = TORQUE INPUT FROM  
DRIVING WHEEL OR MOTOR

$T_2$  = TORQUE OUTPUT  
FROM DRIVEN WHEEL

$$T_2 = F \times R_2$$

$$T_2 = \frac{T_1 \times R_2}{R_1}$$

$$T_1 = F \times R_1$$

$$F = \frac{T_2}{R_2}$$

$$T_1 = \frac{T_2 \times R_1}{R_2}$$

$$F = \frac{T_1}{R_1}$$



LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT VI : PRESSURE AND FLOW MEASUREMENT

SCOPE OF UNIT:

After the completion of this unit, the student will be familiar with some of the instruments which are used to measure the pressure, velocity, and flow rate of air in pneumatic systems.

INFORMATION TOPIC: VI-1

PRESSURE AND FLOW MEASUREMENT  
(Lesson Title)

LESSON OBJECTIVES - THE STUDENT SHOULD BE ABLE TO:

1. Match terms related to pressure and flow measurement.
- 2.1 State Bernoulli's equation and the continuity equations.
- 2.2 Calculate velocity and pressure at any section of pipe using Bernoulli's equation and the continuity equation.
3. Discuss the relationship between velocity and pressure in full flowing pipes.
- 4.1 Describe a simple U-tube manometer and select true or false statements pertaining to the installation and operation of a simple U-tube.
- 4.2 Convert pressure head in inches or feet of water and mercury to pressure head in psi.
- 4.3 Calculate, given the pertinent information, the gage pressure using a simple U-tube manometer.
- 4.4 Describe a differential manometer and select true or false statements pertaining to the installation and operation of a differential manometer.
- 4.5 Calculate, given the pertinent information, the difference in pressure using a differential manometer.
- 4.6 Describe and discuss the operating principles of a Bourdon tube gage.
- 5.1 Describe an impact tube and a Pitot tube, and given the pertinent data, calculate the velocity of air using an impact tube or a Pitot tube.
- 5.2 Describe a Venturi tube and select true or false statements pertaining to the operating principles of a Venturi tube.
- 5.3 Discuss the difference between a Venturi tube and an orifice plate.
- 5.4 Discuss the operating principles of a rotameter.

SUPPLEMENTARY TEACHING/LEARNING ITEMS

1. TM 1: Bernoulli's Equation and the Continuity Equation
2. TM 2: Simple U-tube Manometer
3. TM 3: Differential Manometer
4. TM 4: Bourdon Tube Gage
5. TM 5: Impact Tube

6. TM 6: Pitot Tube
7. TM 7: Venturi Tube
8. TM 8: Orifice Plate
9. TM 9: Rotameter

INFORMATIONAL ASSIGNMENT: (Student)

Industrial Pneumatic Technology, Bulletin 0275-B1. Parker Hannifin Corporation, 1980.

Pease, A. Dudley. Basic Fluid Power. Englewood Cliffs, NJ: Prentice-Hall Inc., 1967.

REFERENCES: (Instructor's Additional Informaiton)

Ower, E., and R. C. Pankhurst. The Measurement of Air Flow. 5th ed. New York: Pergamon Press, 1977.

INTRODUCTION:

The measurement of pressure and flow rate of compressed air is vital if a pneumatic system is to operate safely, economically, and efficiently.

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT VI : PRESSURE AND FLOW MEASUREMENT

INFORMATION TOPIC: VI-1

OUTLINE: (Key Points)

I. Terms and definitions

- A. **Pressure head** - the pressure due to the height of a column or body of fluid
- B. **Velocity head** - the equivalent head through which a fluid would have to fall to attain a given velocity
- C. **Density** - the unit weight of a substance normally expressed in pounds per cubic feet
- D. **Manometer** - an instrument which measures pressure of fluids in which the pressure is indicated by the height of a liquid column
- E. **Bourdon gage** - a mechanical instrument which measures the pressure of fluids (gaseous mass or liquids)
- F. **Drag force** - a force which tends to push or wash away an object when the object is immersed in a moving fluid or when a moving object passes through stationary fluid

II. Bernoulli's equation and the continuity equation

A. Bernoulli's equation (TM 1)

Bernoulli's equation states that in full pipe flow, neglecting frictional loss, the sum of the velocity head and pressure at one section of a pipe is equal to the sum of the velocity head and pressure head at any other section. Mathematically, Bernoulli's equation is expressed as:

$$\frac{V_1^2}{2g} + \frac{P_1}{w} = \frac{V_2^2}{2g} + \frac{P_2}{w}$$

Where

$$\frac{V_1^2}{2g} = \text{velocity head at section (1)}$$

$$\frac{P_1}{w} = \text{pressure head at section (1)}$$

$$\frac{V_2^2}{2g} = \text{velocity head at section (2)}$$



$\frac{P_1}{w}$  = pressure head at section (2)

$V_1, V_2$  = velocities of a fluid at sections (1) and (2), respectively, in ft/sec.

$P_1, P_2$  = pressures of fluid at sections (1) and (2), respectively, in pounds per square feet (psf)

$g$  = gravitational acceleration = 32.2 ft/sec<sup>2</sup>

$w$  = density of water = 62.4 lbs/ft<sup>3</sup>

(NOTE: The above equation is true for frictionless horizontal pipes only.)

#### B. Continuity equation

The continuity equation states that the product of the fluid velocity and the cross-sectional area of a pipe at one section is equal to the product of the fluid velocity and the cross-sectional area at any other section of the pipe, i.e.,  $V_1 A_1 = V_2 A_2$  or  $Q_1 = Q_2$

Where

$V_1, V_2$  = velocities of a fluid at sections (1) and (2), respectively, in ft/sec., or ft/m

$A_1, A_2$  = cross-sectional areas of the pipe at sections (1) and (2), respectively in square feet

$Q_1, Q_2$  = flow rates through sections (1) and (2), respectively in cfs or cfm.

Example: Air flows at 2 ft/sec. and pressure of 1440 psf through a 4 inch pipe. Determine the flow rate and the pressure if the pipe diameter is reduced to 2 inches (neglect friction).

Air velocity at 4 inch section =  $V_1 = 2$  ft/sec

Pipe area at 4 inch section =  $A_1 = \frac{\pi}{4} \left(\frac{4}{12}\right)^2 = 0.0872$  sq.ft.

Pipe area at 2 inch section =  $A_2 = \frac{\pi}{4} \left(\frac{2}{12}\right)^2 = 0.0218$  sq.ft.

Flow rate =  $Q = Q_1 = V_1 \times A_1 = 2$  ft./sec  $\times$  0.0872 sq.ft. = 0.174 cfs

From continuity, the velocity at 2 inch section is

$$V_2 = \frac{V_1 \times A_1}{A_2} = \frac{2 \text{ ft./sec.} \times 0.0872 \text{ sq.ft.}}{0.0218 \text{ sq.ft.}} = 8 \text{ ft/sec.}$$

By Bernoulli's equation between (1) and (2) and solving for  $P_2$

$$\frac{V_1^2}{2g} + \frac{P_1}{w} = \frac{V_2^2}{2g} + \frac{P_2}{w}$$

$$2 \times \frac{2^2}{32.2} + \frac{1440.0}{62.4} = \frac{8^2}{2 \times 32.2} + \frac{P_2}{62.4}$$



Therefore, pressure at section (2),

$$P_2 = 1381.86 \text{ psf.}$$

### III. Velocity and pressure relationships in full flowing pipes

From Bernoulli's equation and the continuity equation, it can be concluded that:

- A. As the cross-sectional area of a pipe decreases, the velocity increases and the pressure decreases.
- B. As the cross-sectional area of a pipe increases, the velocity decreases and pressure increases.

### IV. Pressure measurement

- A. Simple U-tube manometer - a manometer which measures the gage pressure of a fluid. It measures the gage pressure directly, because one arm of the manometer is left open to the atmosphere. It is normally calibrated to read pressure head in inches or feet. (TM 2)

#### 1. Installation and operation

- a. A transparent tube is bent in a U-shaped profile.
- b. Part of the U-shaped section is filled with a liquid (colored), normally water for low pressure reading and mercury for high pressure reading.
- c. One arm of the tube is connected or hooked to the pipe or container containing the fluid whose pressure is to be measured.
- d. The other arm is left open to the atmosphere.
- e. As the fluid in the tube or container impinges on the liquid of the manometer, it imparts a force (pressure).
- f. The force causes the liquid level in the connected arm to fall down and the liquid level in the open arm to rise.
- g. The difference between the liquid levels of the manometer,  $\Delta H$ , (see TM 1) is equal to the pressure head of the fluid in the pipe or container.

#### 2. Conversion factors

- a. Water as the manometer liquid:

$$\text{Pressure, } P \text{ (psig)} = \Delta H \text{ (inches)} \times 0.03613$$

$$\text{Pressure, } P \text{ (psig)} = \Delta H \text{ (feet)} \times 0.4335$$

- b. Mercury as the manometer liquid:

$$\text{Pressure, } P \text{ (psig)} = \Delta H \text{ (inches)} \times 0.4912$$

$$\text{Pressure, } P \text{ (psig)} = \Delta H \text{ (feet)} \times 5.8944$$

Example: Determine the gage pressure of air flowing through an air pipe in which a simple U-tube manometer hooked to the pipe indicates a 10 inch deflection of liquid levels, if the manometer liquid is (a) water and (b) mercury.

(a) Water as the manometer liquid:

$$\text{Pressure head} = \Delta H = 10 \text{ inches of water}$$

$$\text{Pressure, } P \text{ (psig)} = 10 \times 0.0363 = 0.363 \text{ psig}$$

(b) Mercury as the manometer liquid:

$$\text{Pressure head} = \Delta H = 10 \text{ inches of mercury}$$

$$\text{Pressure, } P \text{ (psig)} = 10 \times 0.4912 = 4.912 \text{ psig}$$

B. Differential manometer - a manometer which measures the difference in pressure of fluid between two sections of a pipe (TM 3)

1. Installation and operation

- a. A transparent tube is bent in a U-shaped profile.
- b. Part of the U-shaped section is filled with an appropriate liquid.
- c. One arm of the U-tube is connected or hooked to the upstream section of the fluid pipe and the other is hooked to the downstream side.
- d. As the fluid flows, the pressures on the upstream side and downstream side exert forces on the surface of manometer liquid.
- e. The manometer liquid level in the arm connected to the upstream section will drop while the liquid level in the arm connected to the downstream section will rise.
- f. The difference in pressure between the upstream and downstream points is equal to the difference between the liquid levels of the manometer.

Example: A differential manometer is attached to two sections A and B of a horizontal pipe. The deflection of the manometer liquid is 1.92 ft, the level nearer to A being the lower one. Calculate the difference in pressure in psi between A and B, if the manometer liquid is (a) water and (b) mercury.

a. Water as the manometer liquid

$$\text{Difference in pressure head, } \Delta H = 1.92 \text{ ft}$$

$$\text{Difference in pressure, } P \text{ (psi)} = 1.92 \times 0.4335 = 0.832 \text{ psi}$$

b. Mercury as the manometer liquid:

Difference in pressure head,  $\Delta H = 1.92 \text{ ft}$

Difference in pressure,  $P \text{ (psi)} = 1.92 \times 5.8944 = 11.317 \text{ psi}$

(NOTE: The above calculations are for manometers which are connected or hooked to horizontal pipes.)

C. Bourdon tube gage - a mechanical instrument which measures the gage pressure of fluids (TM 4)

1. Basic components

- a. Socket pipe
- b. Bourdon tube (elliptical in shape)
- c. Linkage
- d. Pointer
- e. Scale

2. Operation of Bourdon tube gage

- a. The fluid whose pressure is to be measured passes through the socket pipe to the Bourdon tube.
- b. As the pressure of the fluid builds up, the internal forces tend to cause the Bourdon tube to straighten or uncoil.
- c. The linkage is connected to the Bourdon tube which translate the unwilling movement to the pointer which indicates the pressure.
- d. The scale is calibrated to read the pressure in psi or any appropriate scale.

V. Velocity and flow measurement

A. Impact tube - an instrument for measuring the velocity of air or gas at low pressure range.

1. Operation of impact tube (TM 5)

- a. The flowing air or gas impinges on the tube head opening at point A which picks the impact pressure of both the velocity head and pressure head of the flowing air.
- b. The tube opening at B picks up the pressure head of the flowing air.

- c. The water in the U-tube reacts to the impact pressures causing the liquid level nearer to A to drop and the liquid level nearer to B to rise.
- d. The difference between the water levels is equal to the velocity head,  $\Delta H$ , measured in feet of water.
- e. The velocity of the air in feet per minute is calculated by

$$V(\text{ft/min}) = 4005 \sqrt{\Delta H}$$

B. Pitot tube - an instrument for measuring the velocity of air or gas at any pressure range (TM 2)

1. Components

- a. The Pitot tube consists of two concentric tubes that are bent at 90° forming the head and the stem of the Pitot tube.
- b. The inner tube which picks up the velocity head and pressure head of the flowing air is provided with a hole at the tip of the Pitot tube head.
- c. The outer tube which picks up the pressure head of the flowing fluid is provided with seven holes some distance from the Pitot tube head.
- d. The stem of the Pitot tube is connected to a manometer which is filled with colored water. One arm of the manometer is connected to the inner tube and the other arm is connected to the outer tube.

2. Operation

- a. The Pitot tube is inserted in a pipe through which the fluid is flowing.
- b. The head of the Pitot tube is positioned at the center of the pipe parallel to the direction of the flow.
- c. The flowing air impinges on the tube openings where the velocity head and pressure head are picked up by the hole on the inner tube and the pressure head is picked up by the openings on the outer tube.
- d. The water in the U-tube of the manometer reacts to the impact pressure causing the water level on the arm connected to the inner tube to drop and the level on the arm connected to the outer tube to rise.
- e. The difference between the water levels is equal to the velocity head,  $\Delta H$ , measured in feet of water.
- f. The velocity of the air in feet per minute is



$$V \text{ (ft/min.)} = 4005 \sqrt{\Delta H}$$

- C. Venturi tube - an instrument which measures the velocity of air normally calibrated to give the flow rate (TM 7)

1. Assembly and operation

- a. A U-tube manometer partly filled with water or any other appropriate liquid is connected or hooked to the Venturi tube.
- b. One arm of the manometer is connected upstream on the air pipe and the other arm is connected to the Venturi throat.
- c. The velocity of the air increases and the pressure decreases as the air approaches the Venturi throat.
- d. The water level on the arm of the manometer connected to the upstream side drops and the water level of the arm connected to the throat of the Venturi rises.
- e. The difference in pressure between the upstream and the Venturi throat is equal to the difference between the water levels,  $\Delta H$ .
- f. Flow rate,  $Q$  in cubic feet per minute, is  $Q(\text{cfm}) = C \sqrt{\Delta H \times P}$

Where  $\Delta H$  is in inches,  $P$  is pressure on the upstream side and  $C$  is a constant determined by test or given by the manufacturer.

D. Orifice plate (TM 8)

This is similar in operation to the Venturi tube, except that a plate with a small opening (orifice) is used and the manometer is connected on the upstream and downstream sides of the plate.

E. Rotameter (TM 9)

1. Components

- a. Float
- b. Conical glass tube

2. Operation

- a. A float is inserted in the conical glass tube.
- b. Fluid flows upwards and the float is pushed up until the drag force due to fluid flow is equal to the weight of the float.
- c. The vertical movement or displacement of the float is proportional to the flow rate.

- d. A calibration scale on the side of the tube indicates the flow rate.

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT VI : PRESSURE AND FLOW MEASUREMENT

INFORMATION TOPIC: VI-1

INTERACTION ITEMS:

1. Is it possible to measure less than atmospheric pressure using a simple U-tube manometer? If yes, what will happen to the liquid level in the arm of the manometer?
2. In measuring the difference in pressure between two sections of a uniform pipe, the water level in the arm of the manometer hooked downstream rises. Discuss why.
3. Discuss why, in a Venturi tube, the water level of the arm of the manometer hooked to the throat of the Venturi rises.

CLASSROOM, LABORATORY, SHOP, OR OTHER ACTIVITIES:

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT VI : PRESSURE AND FLOW MEASUREMENT

INFORMATION TOPIC: VI-1

EVALUATION ITEMS:

1. Match the terms on the right with the correct definition on the left.

- |          |                                                                                                                                                         |                  |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| _____ a. | A force which tends to push or wash away an objects, when the object is immersed in a moving fluid or a moving object passes through a stationary fluid | 1. Pressure head |
| _____ b. | A mechanical instrument which measures the pressure of fluids                                                                                           | 2. Density       |
| _____ c. | The unit weight of a substance normally expressed in pounds per cubic feet                                                                              | 3. Bourdon gage  |
| _____ d. | An instrument which measures the pressure of fluids in which the pressure is indicated by the height of a liquid column                                 | 4. Drag force    |
| _____ e. | The equivalent head through which a fluid would have to fall to attain a given velocity                                                                 | 5. Velocity head |
| _____ f. | The pressure due to the height of a column or body of fluid                                                                                             | 6. Manometer     |

- 2.1. a. State Bernoulli's equation and write the equation taking any two sections (1) and (2) of a pipe.
- b. State the continuity equation and write the equation taking any two sections (1) and (2) of a pipe.
- 2.2. A 6 inch air pipe is reduced to 3 inches. The velocity and the absolute pressure of the air in the 6 inch pipe are 1 ft./sec. and 1500 psf, respectively. Neglecting frictional loss, calculate the velocity and pressure of the air when the diameter of the pipe is reduced to 3 inches.
3. Write true or false for the following statements pertaining to the flow of air through pipes.



- ☐ a. As the cross-sectional area of a pipe decreases, the velocity decreases and the pressure decreases.
  - ☐ b. As the cross-sectional area of a pipe decreases, the velocity increases and the pressure decreases.
  - ☐ c. As the cross-sectional area of a pipe increases, the velocity decreases and the pressure increases.
  - ☐ d. As the cross-sectional area of a pipe increases, the velocity increases and the pressure decreases.
- 4.1. a. Describe a simple U-tube manometer.
- b. Write true or false for the following statement pertaining to a simple U-tube manometer.
- ☐ 1. A simple U-tube manometer is used to measure the absolute pressure of fluids directly.
  - ☐ 2. None of the arms of a simple U-tube manometer is left open to the atmosphere.
  - ☐ 3. The difference between the liquid levels of a simple U-tube manometer is equal to the pressure in psi.
- 4.2. Change (a) 5 feet head of water and (b) feet head of mercury to pressure in psi.
- 4.3. Determine the gage pressure of air flowing through a pipe in which a simple U-tube manometer hooked to the pipe indicates a 20 inch deflection of the manometer liquid levels, if the liquid level is (a) water and (b) mercury.
- 4.4. a. Describe a differential manometer.
- b. Write true or false for the following statements pertaining to a differential manometer.
- ☐ 1. A differential manometer is used to measure the pressure of fluids.
  - ☐ 2. Both arms of a differential manometer must be hooked to the pipe.
  - ☐ 3. The manometer liquid level in the arm connected to the upstream section will rise while the liquid level in the arm connected to the downstream section will fall.
- 4.5. Given a differential manometer attached to two cross sections A and B in a horizontal pipe in which air is flowing, calculate the difference in pressure in psi between sections A and B. The deflection of the manometer liquid level is 1.92 ft, the level near A being lower.

4.6. Describe a Bourdon gage and discuss its operating principles.

5.1. a. Describe an impact tube.

b. Describe a Pitot tube.

c. The manometer of an impact tube or a Pitot tube hooked to an air pipe indicated water level deflection,  $\Delta H$  of 4 inches. Calculate the velocity of the air flowing through the pipe in ft./min.

5.2. a. Describe a Venturi tube.

b. Write true or false for the following statements pertaining to a Venturi tube.

\_\_\_\_ 1. Both arms of manometer are hooked to the throat of the Venturi tube.

\_\_\_\_ 2. The velocity of the air decreases and the pressure increases as the air approaches the Venturi throat.

\_\_\_\_ 3. The water level on the arm of the manometer connected to the Venturi throat rises.

5.3. State the difference between a Venturi tube and an orifice plate.

5.4. Discuss the operating principles of a rotameter.

LESSON PLAN: 1

COURSE TITLE: BASIC PNEUMATICS

UNIT VI : PRESSURE AND FLOW MEASUREMENT

INFORMATION TOPIC: VI-1

ANSWERS TO EVALUATION ITEMS:

1.
  - a. 4
  - b. 3
  - c. 2
  - d. 6
  - e. 5
  - f. 1
  
- 2.1. a. Bernoulli equation states that in full pipe flow, neglecting frictional loss, the sum of the velocity head and pressure head at one section of a pipe is equal to the sum of the velocity head and pressure head at any other section.  
  
Bernoulli equation:  $V_1^2 = P_1 = V_2^2 = P_2$   
  
b. Continuity equation states that the product of the fluid velocity and the cross-sectional of a pipe is equal to the product of the velocity and the cross-section area of any other section of the pipe.  
  
Continuity equation:  $V_1 A_1 = V_2 A_2$  or  $Q_1 = Q_2$
  
- 2.2. Velocity = 4 ft./sec.; Pressure = 1485.46 psf
  
3.
  - a. False
  - b. True
  - c. True
  - d. False
  
- 4.1. a. A simple U-tube manometer is a device which measures the gage pressure of a fluid. It measures the gage pressure because one arm of the manometer is left open to the atmosphere.  
  
b.
  1. False
  2. False
  3. False
  
- 4.2. a. 2.16 psi  
b. 29.45 psi

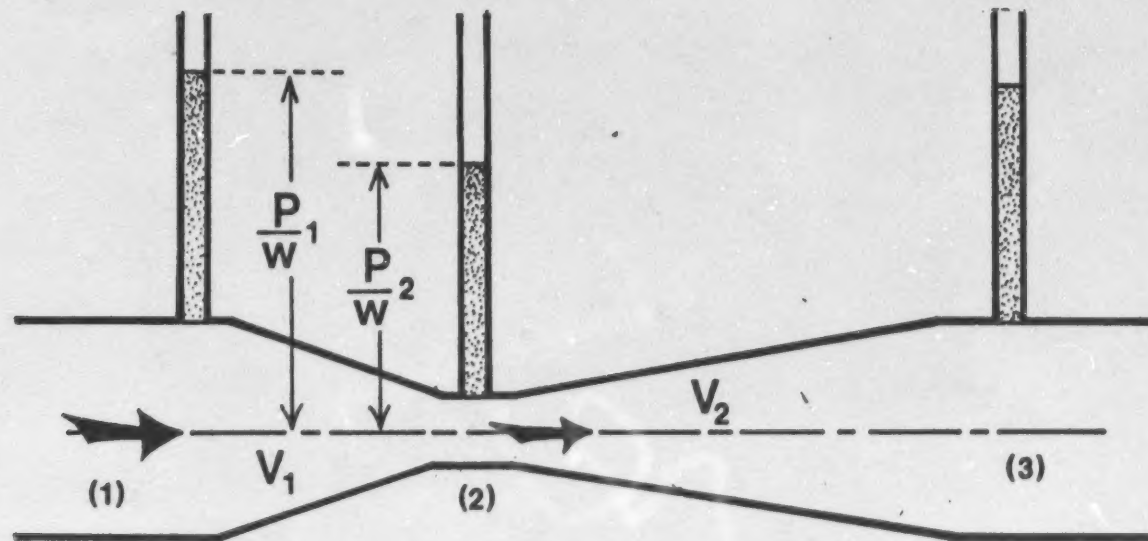
- 4.3. a. Water as the manometer liquid: gage pressure = 0.723 psi
  - b. Mercury as the manometer liquid: gage pressure = 9.824 psi
- 4.4. a. A differential manometer is a manometer which measures the difference in pressure of fluid between two sections of a pipe.
  - b.
    1. False
    2. True
    3. False
- 4.5. 11.31 psi
- 4.6. Bourdon gage is a mechanical instrument which measures the pressure of fluid.
 

Discussion of the operating principals of Bourdon gage should include:

  - a. The fluid whose pressure is to be measured passes through the socket pipe to the Bourdon tube.
  - b. As the pressure of the fluid builds up, the internal forces tend to cause the Bourdon tube to straighten or uncoil.
  - c. The linkage is connected to the Bourdon tube which translate the unwilling movement to the pointer which indicates the pressure.
  - d. The scale is calibrated to read the pressure in psi or any appropriate scale.
- 5.1. a. Impact tube is an instrument for measuring the velocity of air or gas at low pressure range.
  - b. Pitot tube is an instrument for measuring the velocity of air or gas at any pressure range
  - c.
- 5.2. a. Venturi tube is an instrument which measures the velocity of air normally calibrated to give the flow rate
  - b.
    1. False
    2. False
    3. True
- 5.3. The orifice plate is similar in operation to the Venturi tube, except that a plate with a small opening (orifice) is used and the manometer is connected on the upstream and downstream sides of the plate.
- 5.4. Discussion should include:
  - a. A float is inserted in the conical glass tube.
  - b. Fluid flows upwards and the float is pushed up until the drag force due to fluid flow is equal to the weight of the float.
  - c. The vertical movement of displacement of the float is proportional to the flow rate.
  - d. A calibration scale on the side of the tube indicates the flow rate.



# BERNOULLI AND CONTINUITY EQUATIONS



$$\frac{V_1}{2g} + \frac{P_1}{w} = \frac{V_2}{2g} + \frac{P_2}{w}$$

BERNOULLI EQUATION

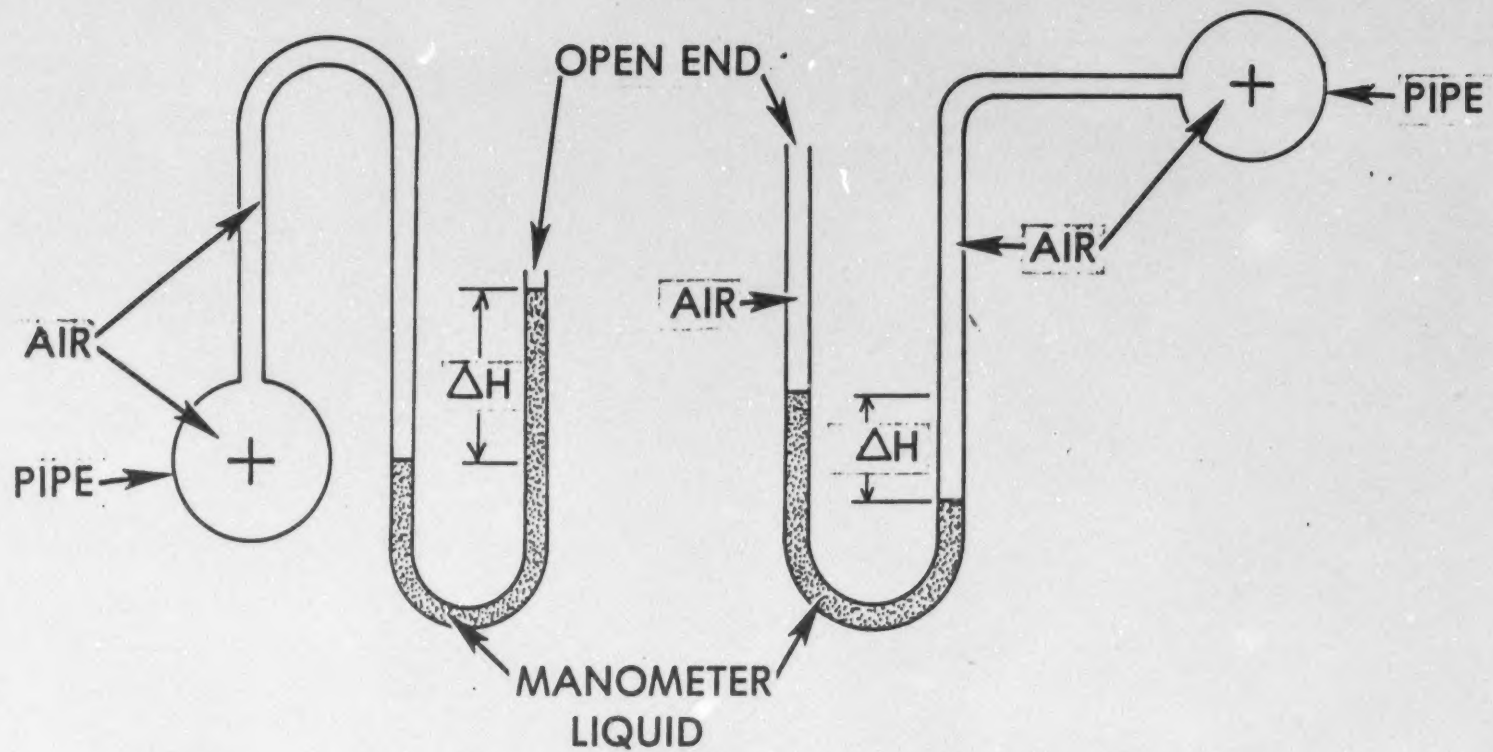
$$V_1 A_1 = V_2 A_2$$

or

$$Q_1 = Q_2$$

CONTINUITY EQUATION

## SIMPLE U-TUBE MANOMETER



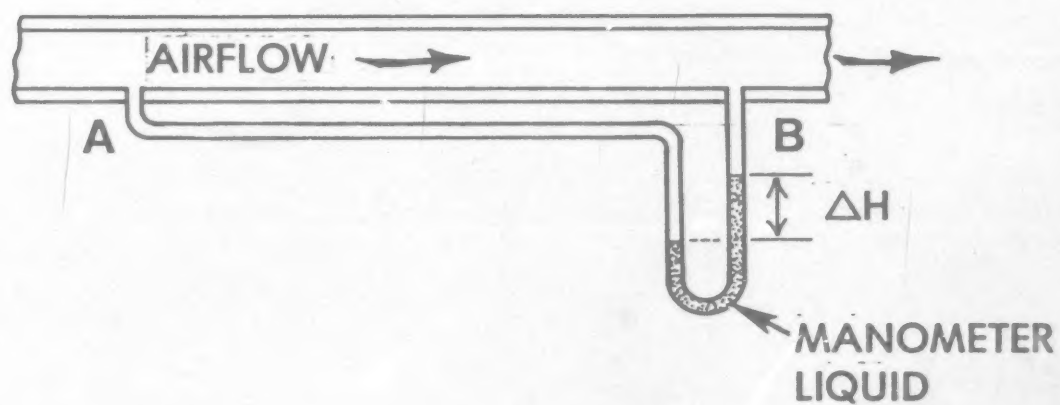
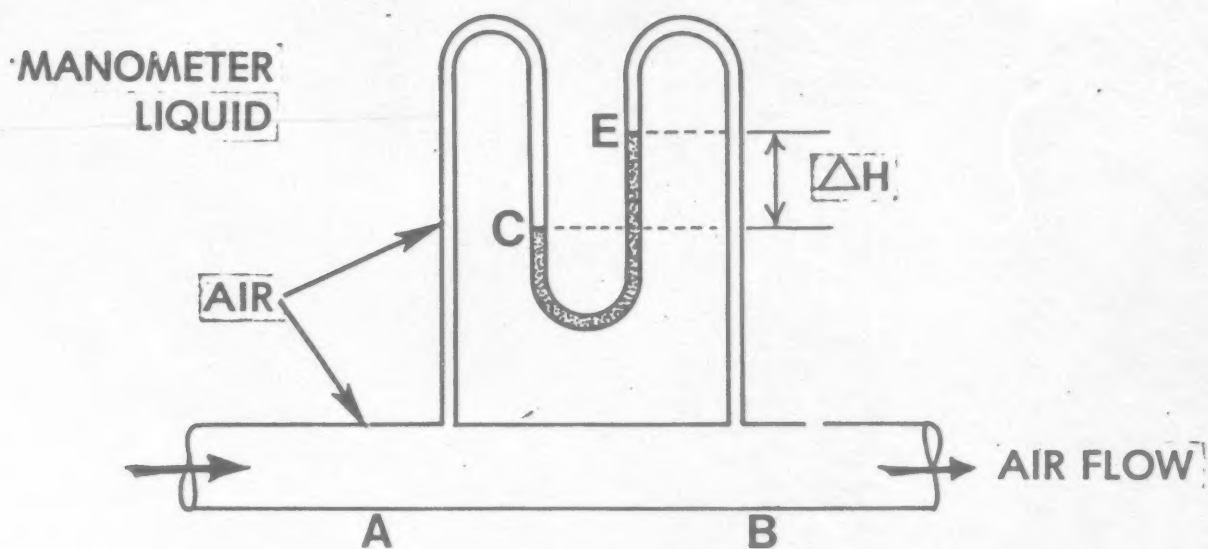
272

PRESSURE OF AIR =  $\Delta H$

273

TM-2

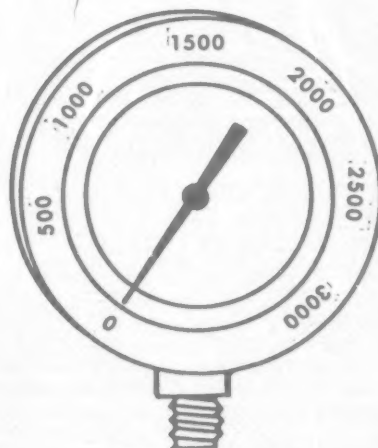
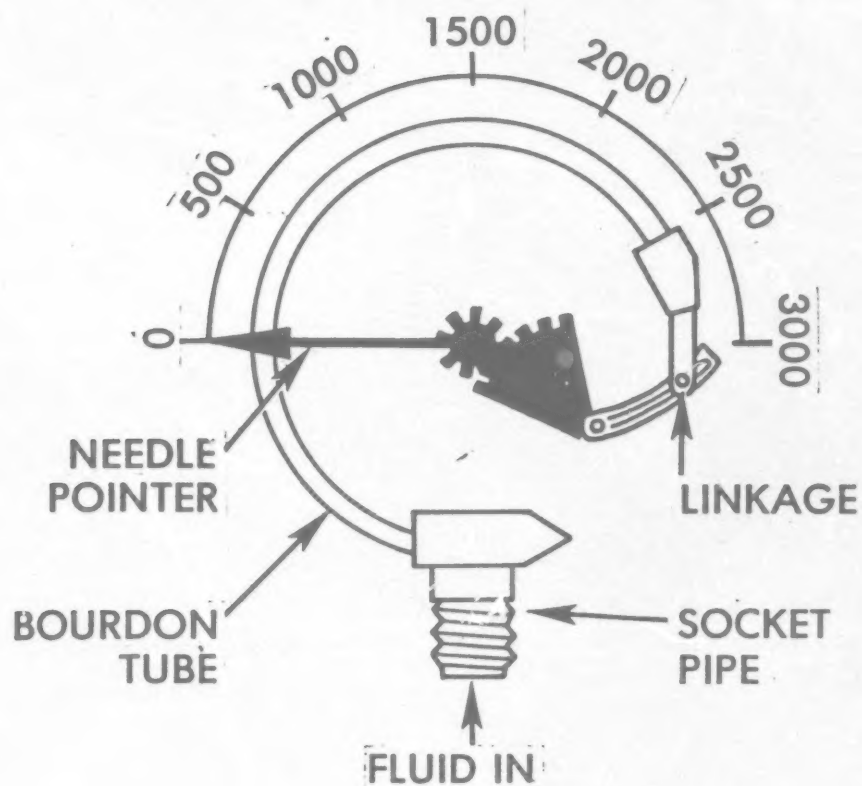
# DIFFERENTIAL MANOMETER™-3



DIFFERENCE IN PRESSURE BETWEEN A AND B =  $\Delta H$

# BOURDON TUBE GAGE

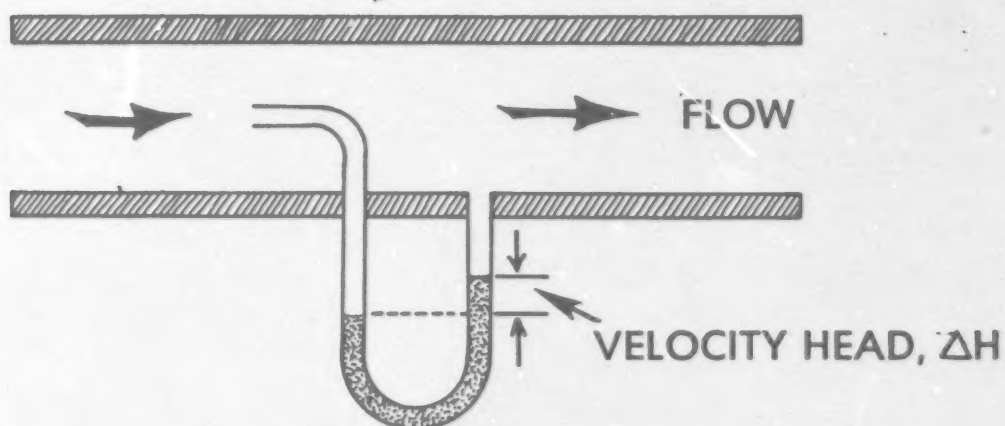
TM-4



VIEW OF BOURDON TUBE GAGE



# IMPACT TUBE

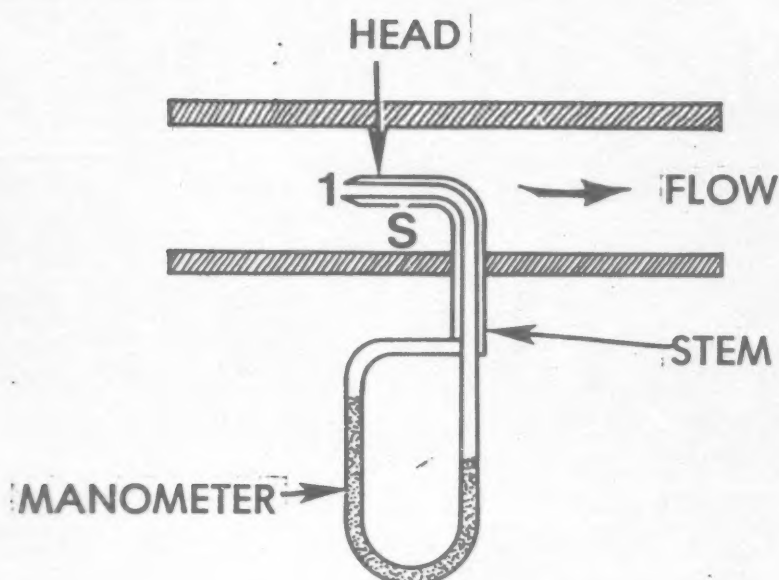


$$\text{VELOCITY, } V(\text{ft/min.}) = 4005\sqrt{\Delta H}$$

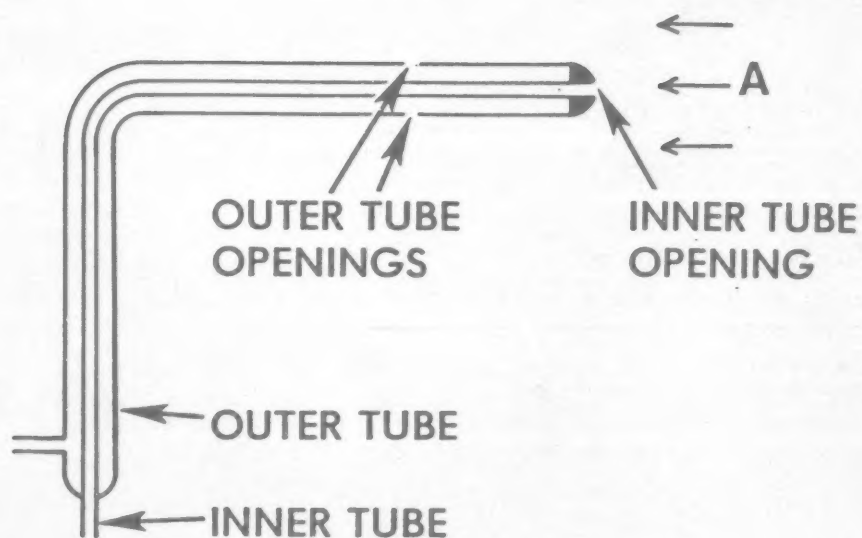
$\Delta H$ , MEASURED IN FT.

# PITOT TUBE

TM-6

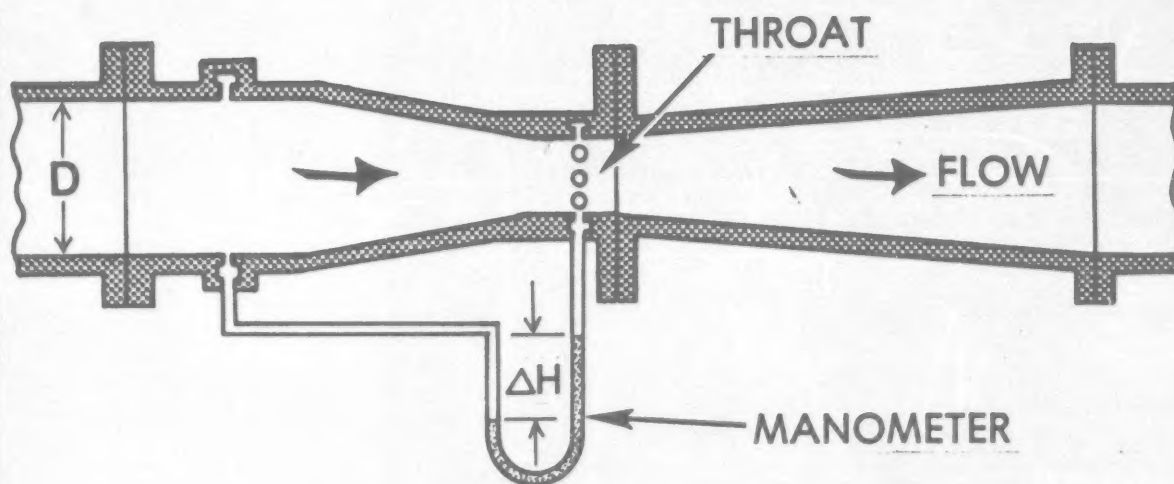


PITOT TUBE AND MANOMETER

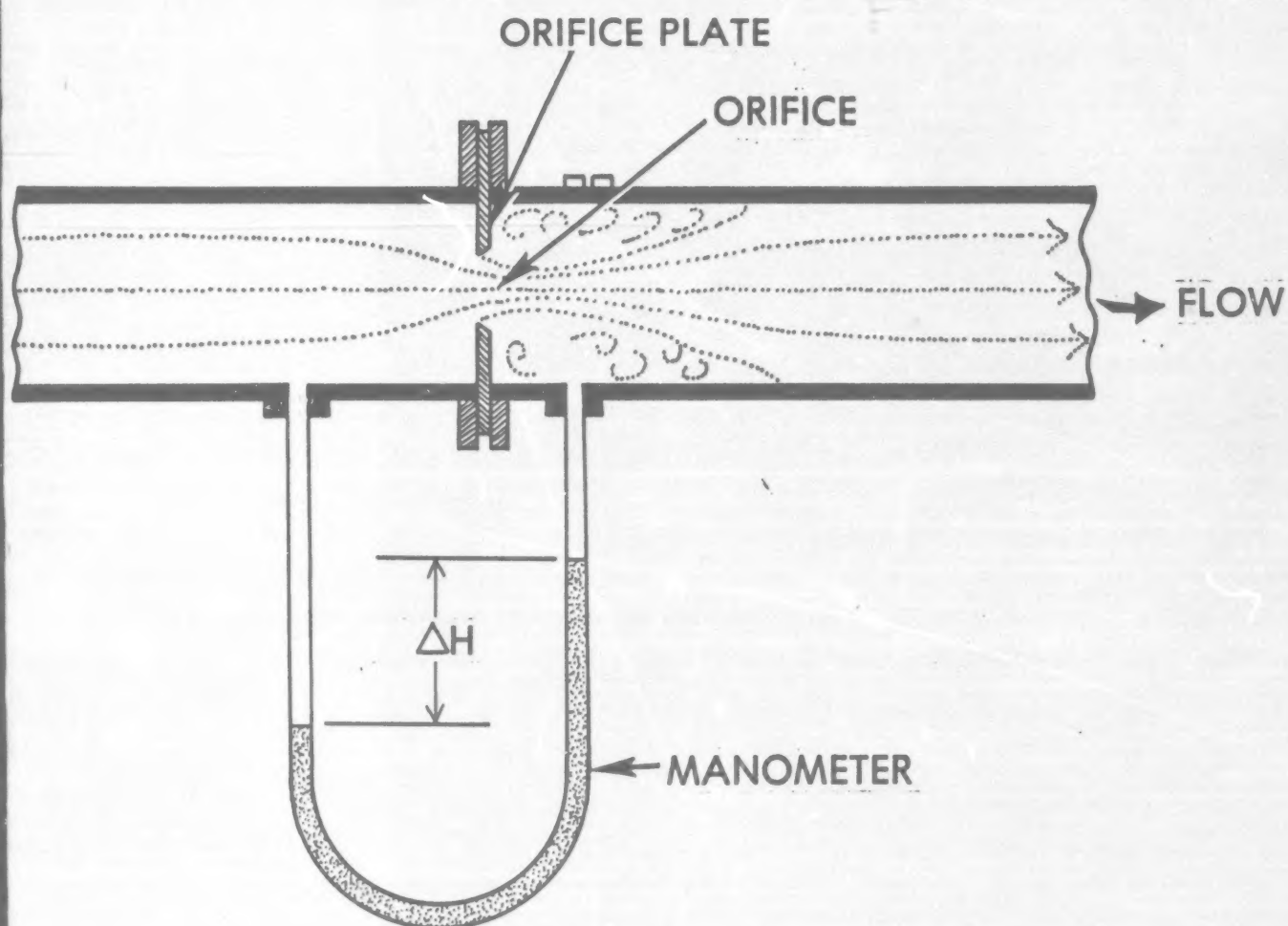


DETAILS OF PITOT TUBE

# VENTURI TUBE



# ORIFICE PLATE





# ROTAMETER

